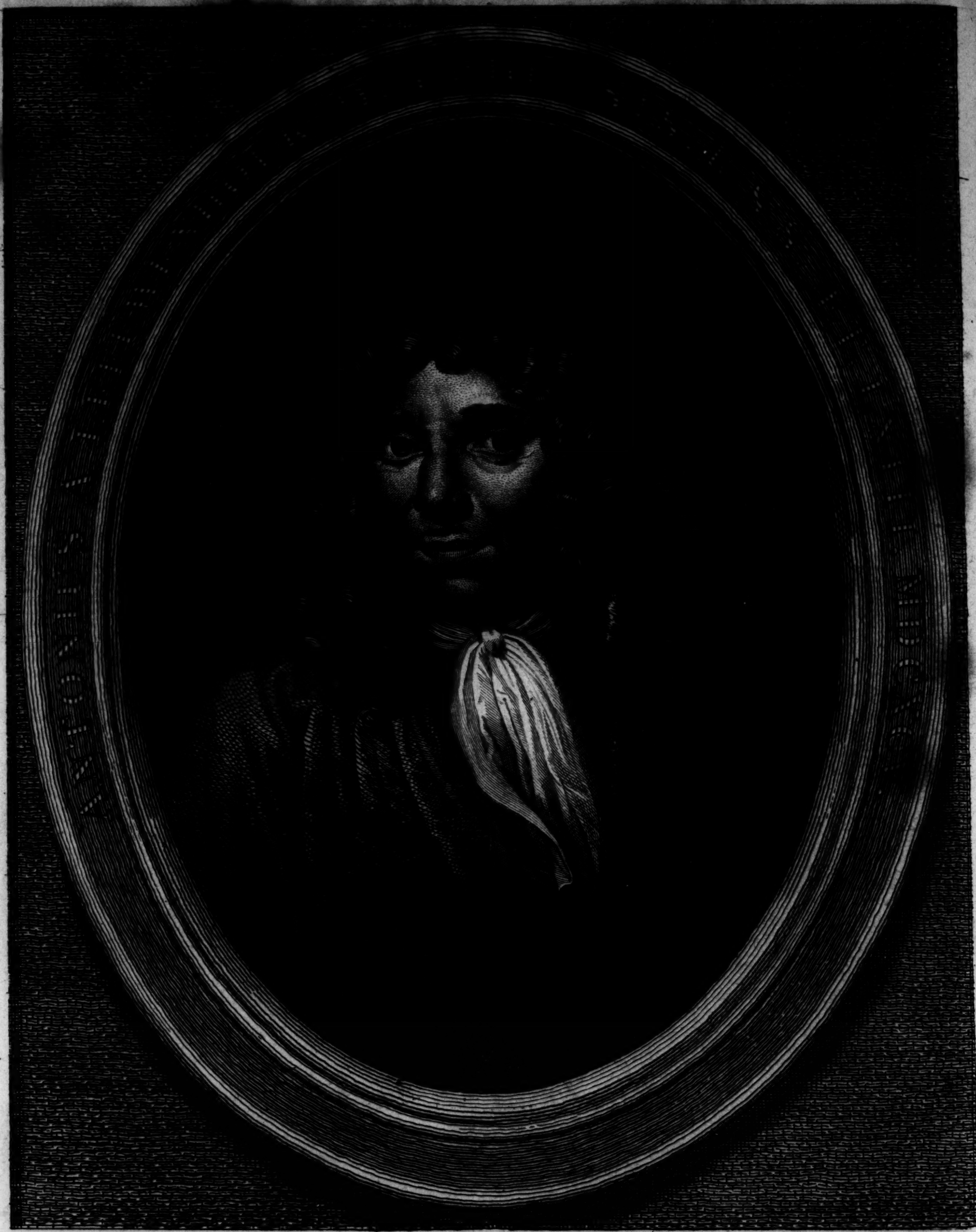




Printed by J. Verkoije.

Engraved by Andrew Smith A.R.A.

ANTONY VAN LEEUWENHOEK,

Fellow of the Royal Society.

*Wy en konnen den Heer en maker van het geheel Al niet meer verheerlyken,
als dat wy in alle zaken, hoe klein die ook in onse bloote oogen mogen zyn, als ze
maar leven en wasdom hebben ontfangen, zyn al-wysheit en volmaaktheit, met
de uiterste verwondering sien uit steken.*

ANTONI van LEEUWENHOEK Brieven 99^{de} missive t'Druck 1696

40213

THE
SELECT WORKS

OF

ANTONY VAN LEEUWENHOEK,

CONTAINING HIS

MICROSCOPICAL DISCOVERIES

IN MANY OF THE WORKS OF NATURE.

TRANSLATED FROM THE DUTCH AND LATIN EDITIONS PUBLISHED BY THE AUTHOR,

By SAMUEL HOOLE.

VOLUME THE FIRST—PART THE FIRST.

Wanneerje schoone dingen fiet,
Vergaep u aen het schepsel niet;
Oock wilt daer op niet blyven staen,
Maer laet uw' sinnen verder gaen?
Ey klimt! o lieve, klimt om hoog,
En metten geest, en mettet oog,
En fiet, dat gy tot hem genaecht;
Die al wat schoon is heeft gemaecht.

Jac. Cats werken, tweede deel pag. 400, 'tDruk, 1726.

Inde hominum pecudumque genus, vitæque volantum
Et quæ marmoreo fert monstra sub æquore pontus.

Virg. Æn. vi. 728, 729.

"Lo, these are parts of his ways: but how
little a portion is heard of him?

Job. xxvi. 14.

LONDON:

PRINTED FOR THE TRANSLATOR,

By G. SIDNEY, BLACK-HORSE COURT, FLEET-STREET;

And sold by G. and W. NICOL, Booksellers to his Majesty, Pall-Mall; J. WHITE, Fleet-Street;
J. & A. ARCH, Gracechurch-Street; and J. WRIGHT, Piccadilly.

M,DCCC.

ADVERTISEMENT.

THE following translation was begun from the Latin Edition published in Holland, but after the translator had proceeded in the work as far as the conclusion of the subjects described in the two first plates, he obtained from Holland the original Dutch Edition. He has carefully compared the two versions, and finds that the Dutch is faithfully rendered in the Latin, and consequently that the sense of the author is not injured by the English being so far taken from thence. The learned reader may himself form a judgment of this, by the following paragraphs, taken from the Dutch and Latin Editions, whereto an English translation is subjoined, and in which care has been taken to follow the Dutch original as literally as possible.

“ Wy willen dan hoopen, dat de onderzoekers der natuurlyke
 “ zaken, die tot nog toe verborgentheden dieper en dieper fullen
 “ op delven, om alsoo meer en meer de waarheid voor de oogen
 “ gestelt hebbende, van veele oude dwalingen, een afkeer te doen
 “ krygen, waar na alle die de waarheid lief hebben behooren te
 “ tragten. Want wy en kunnen den Heer en Maaker van het geheel
 “ Al, niet meer verbeerlyken, als dat wy in alle zaken, hoe klein die ook
 “ in onse bloote oogen mogen zyn, als ze maar leven en wasdom, hebben
 “ ontfangen, zyn Al-wysheit en Volmaaktheit, met de uiterste verwon-
 “ dering sien uit steken.”

Leeuwenhoeks Brieven, 99ste missive.

“ Speramus ergo naturæ indagatores omnem in posterum in id
 “ impenfuros operam, ut ea, quæ adhuc in ejus sinu occulta latent
 “ ulterius in propatulo ponant, atque ita in hominibus, veritatis
 “ lumine illustratis, antiquorum errorum ingenerent fastidium;
 “ quod omnium veritatem amantium studium esse decet. Non enim
 “ hujus universi Dominum atque Opificem melius nos glorificare posse

“ censeo, quam si summam ejus Perfectionem atque Sapientiam, in omnibus rebus, quantumvis nudo oculo exiguis, modo vitam ac incrementum naētis, elucentes, admiremur semper atque celebremus.”

Continuatio Leeuwenhoekii Epistolarum. Ep. 99.

We will hope then, that the enquirers into Nature's works, by diving deeper and deeper into her hidden mysteries, will more and more place the discoveries of those truths before the eyes of all, so as to produce an aversion to the errors of former times, which all those who love the truth ought diligently to aim at. *For we cannot in any better manner glorify the Lord and Creator of the Universe, than that, in all things, how small soever they appear to our naked eyes, which yet have received the gift of life and power of increase, we contemplate the display of his Omniscience and Perfections with the utmost admiration.*

N. B. The Dutch words printed in Italics, are written under the author's portrait prefixed to this Work.

The Dutch motto in the title page, is taken from the works of Jacob Cats, who has been stiled by way of eminence, the Horace of Holland; the learned reader will find it under the head of “Gedachten; Op 'tgesichte van schoone Schepsels.” As the Translator is not possessed of any poetical talents, his readers must be content with plain English prose.

“ When thou beholdest the curious works of nature, do not be content with merely gazing at their beauties, (and canst thou possibly dwell on them without looking higher?) but raise thy thoughts to the contemplation of Him by whom every thing that is fair and beautiful was created.”

Cats's Reflections on viewing the Beauties of the Creation.

The Latin quotation from Virgil, is thus rendered by Mr. Dryden.

“ Hence men and beasts the breath of life obtain,

“ And birds of air, and monsters of the main.”

Dryden's Virgil, Æn. B. vi. l. 986.

INTRODUCTION.

TO those who are acquainted with the works of Mr. Leeuwenhoek, or who have been much conversant in Microscopical studies, this Introduction may appear unnecessary: but those to whom the subject is new, will find so many wonders laid open to their view, as perhaps to induce a doubt of the Author's accuracy in his observations, or his veracity in his narrations. Indeed, the extreme minuteness of many of the subjects on which he treats, is in some instances beyond the reach of our capacities to comprehend,* although we may be fully assured of their existence. In fact, it appears by Mr. Leeuwenhoek's writings, that the difficulty now stated, was

* The Spectator, in one of his papers on the Pleasures of the Imagination, has a passage full to the present purpose, which is as follows:

‘ Nothing is more pleasant to the fancy, than to enlarge itself by degrees, in its contemplation of the various proportions which its several objects bear to each other, when it compares the body of man to the bulk of the whole earth, the earth to the circle it describes round the sun, that circle to the sphere of the fixed stars, the sphere of the fixed stars to the circuit of the whole creation, the whole creation itself to the infinite space that is every where diffused about it: or when the imagination works downward, and considers the bulk of a human body, in respect of an animal a hundred times less than a mite, the particular limbs of such an animal, the different springs which actuate the limbs, the spirits which set these springs a going, and the proportionable minuteness of these several parts, before they have arrived at their full growth and perfection. But if, after all this, we take the least particle of these animal spirits, and consider its capacity of being wrought into a world, that shall contain within those narrow dimensions a heaven and earth, stars and planets, and every different species of living creatures, in the same analogy and proportion they bear to each other in our

made a matter of objection by several of his contemporaries, therefore the following passage in his own words, will serve to state the objection, and the manner in which it was answered by the Author himself.

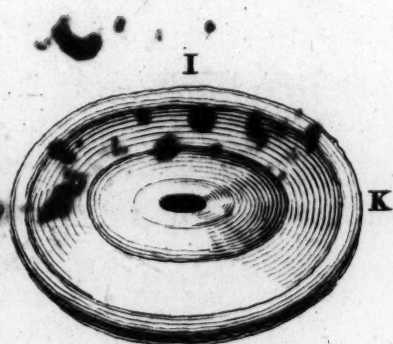
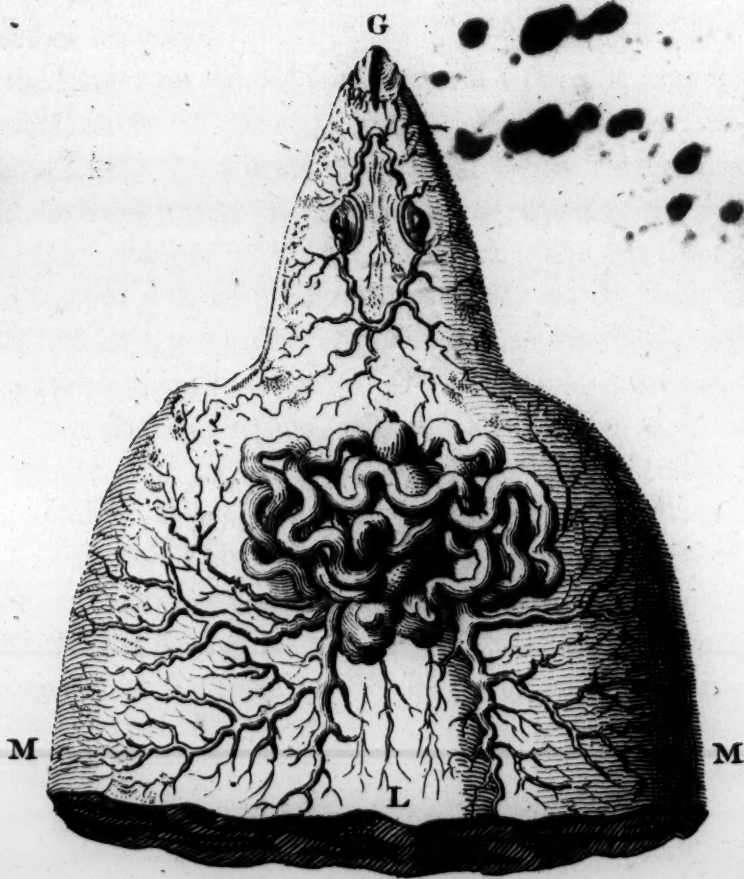
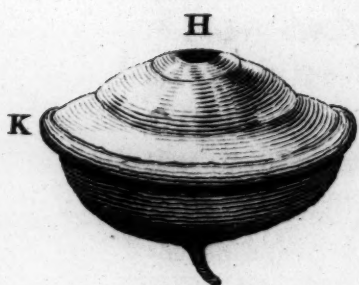
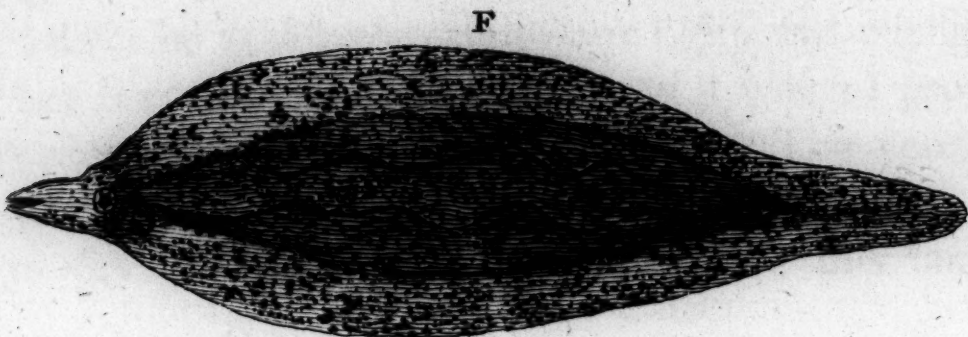
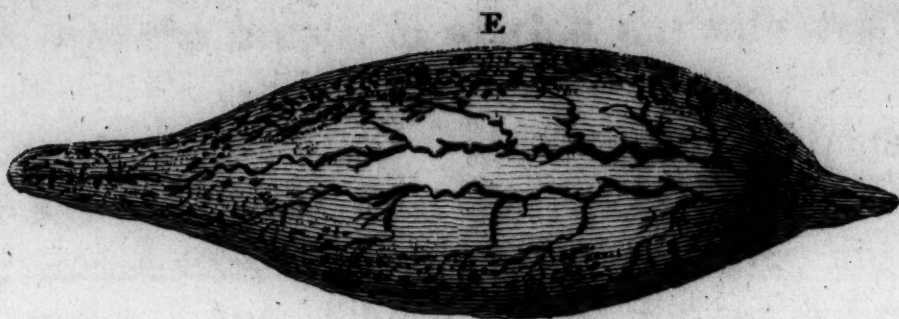
‘ I have often heard, that many persons dispute the truth of what I advance in my writings, saying that my narrations concerning animalcules, or minute living creatures, are merely of my own invention. And, it seems, some persons in France have even ventured to assert, that those are not in truth living creatures, which I describe as discoverable to our sight, and alledge, that after water has been boiled, these particles in it which I pronounce to be animalcules will be still observed to move. The contrary of this, however, I have demonstrated to many eminent men, and I will be bold to say, that those gentlemen who hold this language, have

own universe; such a speculation, by reason of its nicety, appears ridiculous to those who have not turned their thoughts that way, though at the same time it is founded on no less than the evidence of a demonstration. Nay, we may yet carry it farther, and discover in the smallest particle of this little world, a new inexhausted fund of matter, capable of being spun out into another universe.

‘ I have dwelt the longer on this subject, because I think it may shew us the proper limits, as well as the defectiveness of our imagination; how it is confined to a very small quantity of space, and immediately stopt in its operations, when it endeavours to take in any thing that is very great, or very little. Let a man try to conceive the different bulk of an animal, which is twenty, from another which is a hundred times less than a mite, or to compare in his thoughts, a length of a thousand diameters of the earth, with that of a million, and he will quickly find that he has no different measures in his mind, adjusted to such extraordinary degrees of grandeur or minuteness. The understanding, indeed, opens an infinite space on every side of us; but the imagination, after a few faint efforts, is immediately at a stand, and finds herself swallowed up in the immensity of the void that surrounds it: our reason can pursue a particle of matter through an infinite variety of divisions; but the fancy soon loses sight of it, and feels in itself a kind of chasm, that wants to be filled with matter of more sensible bulk. We can neither widen, nor contract the faculty to the dimensions of either extreme. The object is too big for our capacity, when we would comprehend the circumference of a world: and dwindles into nothing, when we endeavour after the idea of an atom.’

‘ SPECTATOR, No. 420.’





M

L

M

' not attained to a degree of proficiency to observe such objects truly.
 ' For my own part, I will not scruple to assert, that I can clearly
 ' place before my eye the smallest species of those animalcules con-
 ' cerning which I now write, and can as plainly see them endued
 ' with life, as with the naked eye we behold small flies, or gnats
 ' sporting in the open air, though these animalcules are more than a
 ' million of degrees less than a large grain of sand. For I not only
 ' behold their motions in all directions, but I also see them turn
 ' about, remain still, and sometimes expire; and the larger kinds of
 ' them I as plainly perceive running along, as we do mice with the
 ' naked eye. Nay, I see some of them open their mouths, and move
 ' the organs or parts within them; and I have discovered hairs at
 ' the mouths of some of these species, though they were some thou-
 ' sand degrees less than a grain of sand.

' But since it is pronounced to be incredible, that within the space
 ' occupied by a grain of sand so many animalcules can be contained,
 ' and that it is impossible for me to calculate truly such numbers, I
 ' have thought on the following method of computation, to place
 ' this matter in a clearer light. I lay it down as a position or truth,
 ' that with the microscope I can see the space occupied by a grain of
 ' sand* magnified to the size represented by the circle A B G C.
 ' Next, I suppose that I observe within this space an animalcule
 ' swimming or running along, and appearing of the size represented
 ' at D. Taking the measure of this by my eye, I conceive the axis
 ' or thickness of the animalcule thus pictured at D, to be the twelfth
 ' part of the axis of the grain of sand represented by A B G C; there-
 ' fore, by the common rules of arithmetic, the solid contents of a
 ' sphere or globe whose circumference is described by the circle
 ' A B G C, will be 1728 times larger than a sphere of the size of D.

* ' A grain of sand the Author in another place describes to be of that sort called scowering,
 ' sand, or glass-grinders sand.

‘ Next, I observe another kind of animalcule, which, measuring, by
‘ my eye through a good microscope, I judge the axis or thickness
‘ of it to be one fifth, but suppose it only a fourth part of the size of
‘ the first animalcule D, such as is represented by the circle E, and
‘ then, by the same rule, the size of D must be 64 times larger than
‘ that of E; and if this last number be multiplied by the former,
‘ (1728) we shall find that 110,592 animalcules of the size of E,
‘ (supposing their bodies to be of a spherical figure), will be required
‘ to make up the size of the sphere A B G C. Lastly, I perceive a
‘ third kind of animalcule, the size of which appears to be only a
‘ tenth part of the animalcule at E, such as the point at F denotes;
‘ and that consequently, one thousand of these will be more than equal
‘ to the size of that at E. And, if this number be again multiplied by
‘ the former, it will be plain to demonstration, that more than an
‘ hundred millions of animalcules can be contained within the com-
‘ pafs of a grain of sand*.’

This passage respects the size of animalcules, which the Author represents by comparison with the known size of a grain of sand; other minute objects which he frequently describes, are, the vessels in the bodies of insects, the threads of Spiders, the filaments or threads of wool, the fibres composing the flesh of animals and the like. All these he considers as of a cylindrical form, that is to say,

* ‘ The solid contents of spheres being in the same proportion as the cubes of their axes, the mathematical demonstration of the Author’s position is set down by him thus:—

12	4	10	1728
12	4	10	64
144	16	100	6912
12	4	10	10368
1728	64	1000	110,592
			1000
			110,592,000

if hollow, like a round pipe, and, if solid, like a round stick, wire, or rope, and he conveys to his readers an idea of their minuteness, by comparing them with the known size of a single hair. The method used by him in ascertaining this proportion he describes as follows :

‘ In examining the intestines of flies and other insects by the microscope, I have discovered vessels conveying the blood and juices, the smallest ramifications or branches whereof appeared to me more than two hundred thousand times less than an hair of my beard. And I will here explain how I compute this proportion, which to many may appear wonderful.

‘ I have a plate of copper, with many lines engraven on it, and divided into a number of small equal parts. I then carefully observe how many of these parts one hair taken from my beard, and seen through the microscope, appears to cover. Supposing that the diameter of this hair, when magnified, appears equal to fifty of those parts, then with the point of a needle I trace on the copper a line, of the same size by the naked eye as is equal to one of those small veins or vessels in a fly, seen through the microscope ; and I find that nine of those small lines so traced with a needle, when placed close together, are a fiftieth part of the diameter of the hair. If then 450 diameters of those small veins which I most plainly see in a fly are no more than equal to the diameter of one hair taken from my beard, it follows,* by the rules of arithmetic, that one of such

* Mr. Leeuwenhoek here considers the hair to be round, as well as the small vessels he alludes to, and, supposing each of these to be cut through or across the middle, the section would exhibit a circle. Now the areas of circles being in proportion to the squares of their diameters, the Author's proposition is mathematically demonstrated thus :

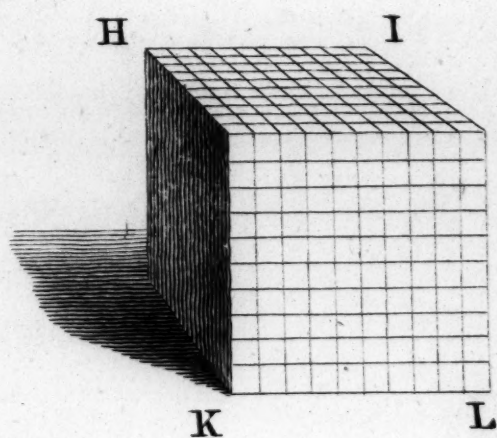
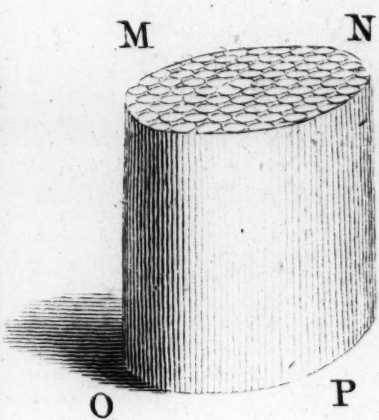
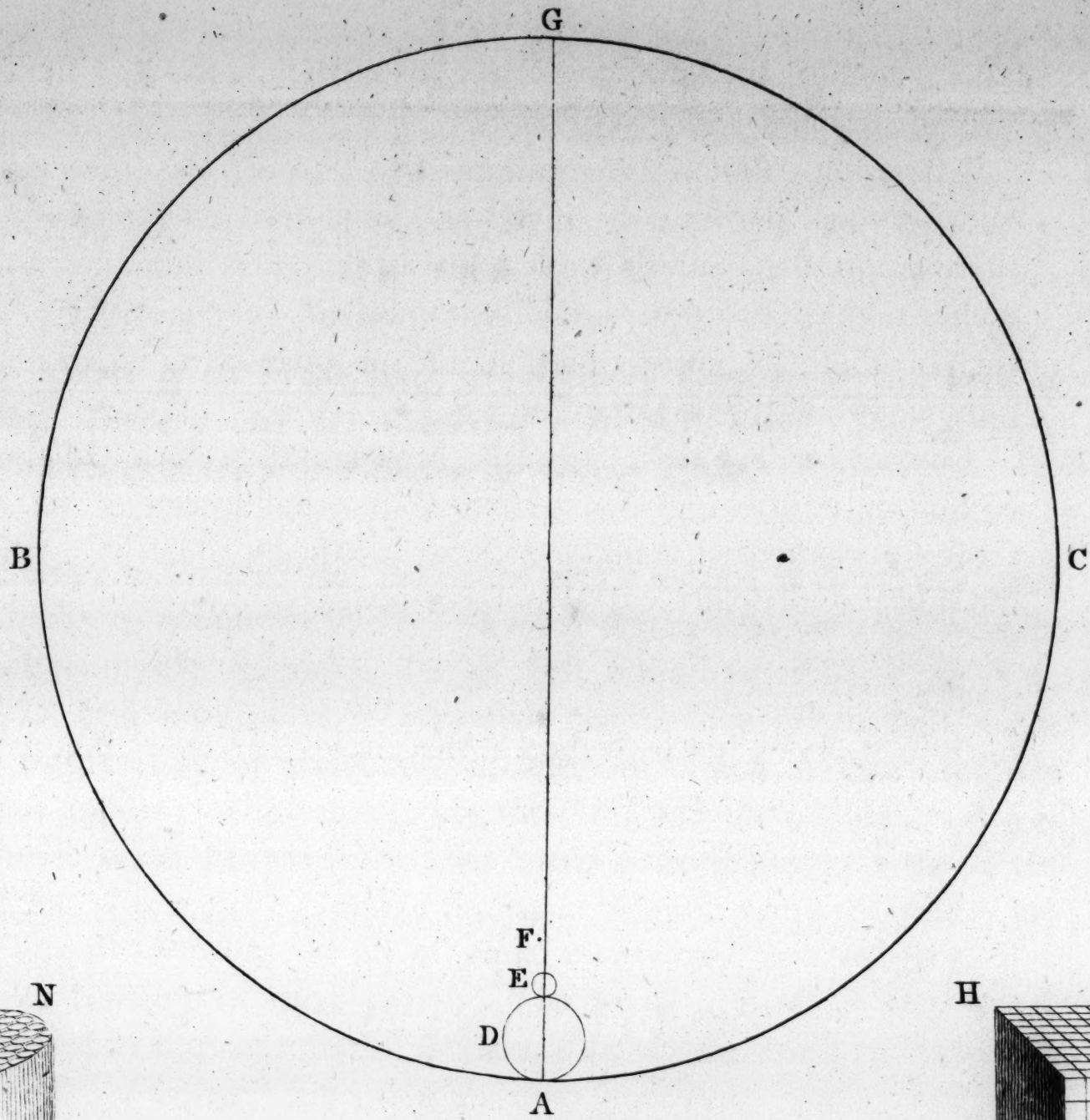
$$\begin{array}{r}
 450 \\
 450 \\
 \hline
 22500 \\
 1800 \\
 \hline
 202,500
 \end{array}$$

'hairs is more than 200,000 times larger than those very small blood
'vessels in a fly.'

The author sometimes computes the size of small objects by aliquot or equal parts of an inch, and, for the more readily placing these before the reader's view, the translator has subjoined a scale of inches divided into several different numbers of equal parts, and in each of these divisions is marked the proportionate size of the same number of parts in a square inch.

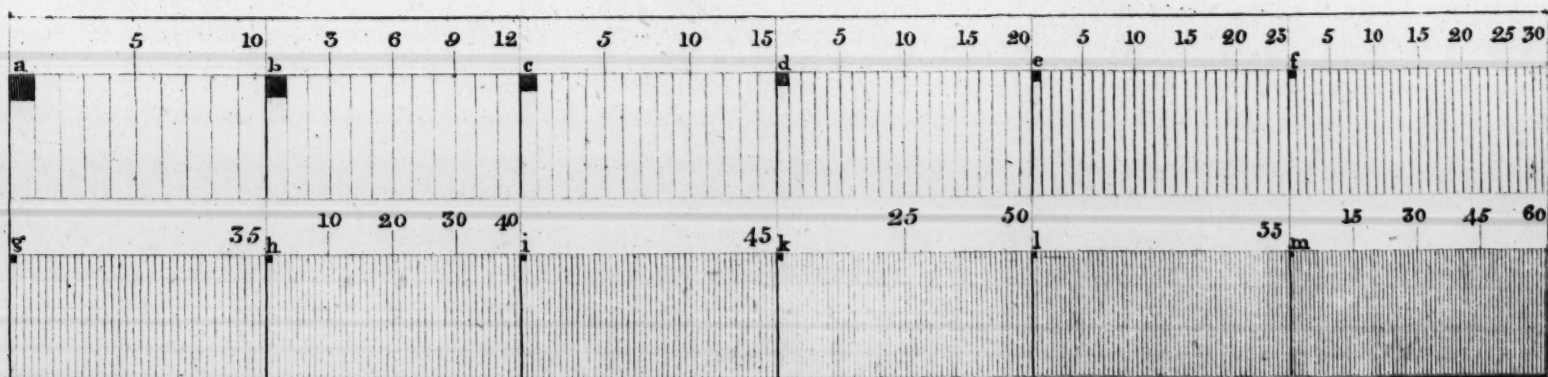
Further, at H I K L, is given a representation of a cube, and at M N O P, a drawing of a cylinder, in order to convey an idea of those figures to such readers as have not been much conversant in the doctrine of solids. The number of parts or circles contained in the cylinder, will not be found to answer so exactly to the arithmetical computation as those in the cube, and this is occasioned by the interstices or spaces between the circles in the cylinder, which only touch each other in a point,





*The Aliquot parts of a Square Inch are
marked at the letters a.b.c.d.&c.*

a denotes the	100	p ^{ts}	g	1225
b	144		h	1600
c	225		i	2025
d	400		k	2500
e	625		l	3025
f	900		m	3600



A Scale of Inches divided into different numbers of aliquot or equal parts.



OF THE OAK.

The Nature of its Production ; the different Degrees of Goodness in Oak Timber ; and the Causes of that Difference. The Author's Opinion as to the proper Season for felling Timber.

IN order to form a true judgment of the nature of this Tree, and the better to comprehend the following descriptions of the * vessels, which compose the same, let us first attend to Plate I. *fig.* 1 †, B C D, and imagine it to represent the surface of an Oak when cut transversely or across the middle, on which surface eighteen circles appear ; which circles are the clear and undoubted marks of eighteen years growth, the tree being increased every year by the addition of one circle, (and in the latter of those years the circles are the largest, though not all of equal magnitude, but in proportion to the fertility of each year.) The small portion of this wood, described in the next figure is marked in the sixteenth circle by the letter E. Farther, supposing the tree to be sawn across, as above-mentioned, and afterwards planed or polished, we shall observe throughout the surface, streaks or creases, reaching from the centre A, to the circumference B, and these are vessels conveying the nu-

* By the word vessels, are to be understood, throughout this Work, small tubes, or pipes, running in different directions, in the subjects treated of.

† This figure, which in the original, is only so many circles, the Translator has caused to be engraved from a piece of Oak of the size here described ; at F is represented a knot which was in the tree.

tritive juices of the plant outwards towards the bark, as in the next figure will be more fully explained.

Fig. 2, A B C D, represents a small piece of Oak, drawn as nearly as could be done, according to its appearance seen through a microscope, prepared by me for that purpose, and which piece of wood appears to the naked eye of the size represented at *fig. 2*, X.

The dark shades at F F, F F, indicates the part where, towards Autumn, the vegetation and increase for that year cease; and about this time, and in this part, the wood becomes exceeding hard, being composed of such small vessels, that it is difficult, and at last impossible to distinguish them, for which reason they assume the appearance of dark streaks or shades. Between the letters F F, F F, is contained that space, or thickness, which the tree acquires through its circumference, in the space of one year.

This species of timber tree, has five different kinds of vessels, three rising perpendicularly, and two extending, or spreading horizontally.

E E E, represent the first sort of these perpendicular vessels, which are very large, and are produced in the spring, with the first rise of the sap. The insides of these vessels are full of a kind of vesicles, or little bladders, composed of very thin membranes, or skins, and these are to be seen in *fig. 3*, where, at the letters L K I M, is represented a section of one of these large vessels, divided longitudinally, and seen through the microscope.

The second sort of these perpendicular vessels is much smaller, and is also composed of exceeding fine membranes, intermixed with a kind of spots, which by the microscope, appeared to my eye like globules, or little balls, as represented in *fig. 4*, O N, which exhibits one of these second sized vessels, divided longitudinally.

The third kind of these perpendicular vessels is exceeding small, but in great numbers: likewise composed of excessively minute

membranes, and these are also represented when cut longitudinally, or lengthways, at *fig. 4*, P Q.

All these perpendicular vessels, which are found in so small a piece of wood as that before represented, and which in size, is about the ninetieth part of a square inch, do amount in number, in my opinion, to twenty thousand; so that an Oak tree of four feet in circumference* contains, according to my computation, more than three thousand two hundred millions of these perpendicular vessels, and in a tree of no more than one foot in circumference, will be found two hundred millions of such vessels.

These perpendicular vessels do, for the most part, infuse, or instil their juices into other vessels, which are almost innumerable, lying in an horizontal position in the tree, and by the means of which it's bulk or thickness is daily increased: these vessels are of two sorts.

Fig. 2, G G G, represents one sort of these horizontal vessels, which originally, or at the first formation of the plant, are derived from the marrow, or pith, in the centre of it; but afterwards, in great numbers, take their origin from the perpendicular vessels. These vessels appeared to my eye like dark streaks; but in order to examine them more clearly, I cut a piece of the wood lengthwise, so that they were cut exactly across, and then each of them appeared to be formed of five, six, or even seven vessels joined one on another, as they are represented in *fig. 4*, intermixed among the perpendicular vessels.

The other sort of horizontal vessels, lying in great numbers or clusters, closely joined to each other, though not evenly diffused throughout the wood, when examined in their horizontal position, appear as in *fig. 2*, A B, or C D, (but when cut transversely,

* The circumference of a circle being about three times it's diameter, a tree of four feet in circumference, will be sixteen inches in diameter, and one of a foot in circumference, four inches diameter, the size represented in *fig. 1*.

they are represented as seen by the naked eye, in *fig. 5*, R S,) and where they are represented magnified and seen longitudinally in *fig. 2*, I have in many places drawn cross lines, to represent what I conceive to be minute valves, and though I could not see them so distinctly, as here they are drawn, yet I cannot doubt of their existence, having frequently seen these valves in other woods, and particularly, very distinctly in the Elm; besides, it seems evident to me, that without such valves the tree could not be increased in its bulk, on account of the great force required to separate and loosen the bark from the tree, in the time of spring, and also for the violent bursting open of the bark, to allow for the growth and increase of the wood: and if there were not such valves, the juices, which by the action of the sun are drawn outwards, would, at sun set, when that motion of the juices ceases, be drawn back again, and their exertions to distend the bark become fruitless. A portion of these vessels is represented in *fig. 4*, TV, which figure is drawn from a microscope of greater magnifying power than that from which the perpendicular vessels are drawn, in order that these horizontal ones may be more clearly seen: and in this small piece of wood, and in this little space, which is no more than the seven hundredth part of a square inch, are more than two thousand vessels.

It is well known that there is a great difference in Oak Timber, namely, whether it grew in mountainous situations, or low lands, and whether in warmer or colder climates, and lastly, whether it was of quicker or slower growth. As to the specimen of Oak which has been just described, it was taken from a tree of the best quality, very compact and close grained, and which had been very flourishing in its growth.

Oak timber of this superior quality we must not expect to find in the Northern or cold countries, but in the warmer ones. The very best timber that we have here, in Holland, is brought down the

Rhine from the places of its growth, which are nearly in the same parallel of Northern latitude with ourselves. The Oak which we have from Riga, Koningsberg, and Dantzick, is very perishable, and of a spongy nature, because it grows in a colder climate, and increases in it's bulk much more slowly than that before-mentioned ; but yet this wood, though so perishable, is deemed the best for making beer-barrels, because it does not impart any ill taste to the beer, the reason of which I take to be, that in cold climates the Oak does not acquire so much acrid salt as it does in warmer ones ; but I do believe, that if the better species of Oak, after being cleft into staves, were to be soaked in water for a certain time, this acrid salt would be extracted from it, and that the casks made of it would be greatly superior to those made of Riga Timber.

The Oak, as has been before observed, in the beginning of its growth every spring, produces very large vessels, but the rest of the year much smaller ones ; consequently, when the tree so flourishes as to acquire an increase in it's semi-diameter, or on one side of it's outward surface, of one half, one third, or a quarter of an inch, there will be in this space only one series, or row of such large vessels ; but on the contrary, where the increase is slow, then, within the same space of one half, one third, or a quarter of an inch, there will be formed from twenty to ten, or eleven such rows of large vessels. This great number of large vessels in so small a space, not only renders the wood very porous and brittle, but also very perishable, especially if it is used in works exposed to much moisture, and where there is no free current of air : and hence it is, that ships built of French or English Oak, are much more durable than those built of timber growing in the more Northern and cold countries.

In order, more clearly, to explain the nature of the best Oak timber, let us revert to *fig. 2*, representing a portion of a tree which, in one year, had acquired in thickness almost a sixth part of an inch

in it's semi-diameter, or one third of an inch in the whole, and in this, one row or circle, and no more, of the very large vessels, before described, had been formed. Then, to discern the difference between this timber and that brought from Riga and Koningberg, let us attend to *fig. 6*, A B C D E F, wherein is exhibited a small piece of such timber cut transversely, and drawn from the microscope.

The piece of wood which, in this figure, is represented by A B C, or D E F, contains about the fifteenth part of an inch in length*, and this length, or rather this thickness, the tree had acquired in two years growth, so that A B denotes the thickness produced in the tree in one year, and is about the thirtieth part of an inch in length; B C or E D, indicate the increase of the following year; A B C and F E D represent the larger horizontal vessels, which in *fig. 2*, are explained by A B or C D; and the dark lines H H H H, indicate the smaller horizontal ones, which in *fig. 2*, are described by G G G: all the round cavities, of which there are three different sizes represented in this figure, and which are found within the compass of the thirtieth part of an inch in length, are the three different sorts of perpendicular vessels before described. Hence we see that in a tree, which is augmented in size, in it's semi-diameter, one inch, or in the whole diameter two inches and no more, in the growth of thirty years, there will be formed thirty rows, or series of large vessels; from whence it follows, that the greatest part of Oak Timber, of such slow growth, must be very soft and perishable: and if on the other hand we consider, that Oaks growing in a warmer climate may, in one year, increase in size, in their semi-diameter half an inch, or an inch in their whole diameter, we may easily perceive how large a portion of wood will be formed in them, having only one row of the large vessels in it, and how firm, solid, and durable such wood must be.

* This size is represented in *fig. 6*, at X.

Let a tree of flourishing growth be increased in magnitude, in the space of a year, one fourth part of an inch, in such a space will be produced one circle of the large vessels; another tree growing in a colder climate shall require eight or ten years growth to increase in the same degree: in this last tree, within the fourth of an inch space will be formed eight or ten circles of large vessels, the necessary conclusion is, that Oak Timber growing in cold climates must be soft and perishable, and it must be acknowledged that Oak timber growing in this country of Holland, is superior in quality to that produced in more Northern latitudes: again, that the Oak Timber of Brabant and Flanders, is superior to ours, and lastly, that the French and English Oaks are the most excellent of all.

One thing must however be considered, which is, that the very largest Oaks are not always so valuable as trees of a more moderate size, that is to say, if they were of good growth, and are free from decay; for though large trees, in the first thirty, forty, or fifty years may grow very fast, and produce excellent timber, yet when they come to the age of an hundred, or an hundred and twenty years, the circles of wood added every year, become very narrow, and the thickness increases slowly, so that the large vessels in the wood approach near together, and consequently the exterior or outward parts of such large timber become very soft, in comparison with the inner part of it.

It is the general opinion in this Country that timber is much more solid or durable when felled in winter than in summer. But I think that if we examine this opinion, we shall find it to be erroneous.

It is true, that if timber be felled in the summer time, the bark can much more easily be separated from it than in the winter; for the wood newly formed each year always adheres to the bark, and the bark is every year propelled or driven outwards from the last

year's wood, and as the tubes or vessels of which such newly formed wood is composed, are during the time of their growth not solid, but of a very soft texture, this is the reason why the bark can be so easily stripped off in the summer time. But that any part of the tree, except that of the new growth, should be more solid in winter than in summer, seems to be altogether impossible; for it is plain to demonstration that all trees are composed of multitudes of small tubes or vessels, which are formed every year by the tree's growth, and that when once formed they preserve their shape and size, without any alteration, although the tree be above an hundred years old. These tubes, which in all seasons are filled with juices, are neither less in winter nor larger in summer, for the juice which circulates through them is at all times the same. But if it were possible that the substance of trees in winter could be more close or compact, and in summer more spongy or distended, it would follow that the hard and dead bark surrounding the tree would in winter be separated from the wood, and in summer more split open than it is found to be; but since we do not observe this to happen in either instance, it must be the better opinion, that timber felled in summer is equally good with that cut down in winter; and if any one will take the trouble to examine those small chinks or fissures which are produced in the bark during the tree's growth in summer, he will find that trees are not increased in their size or substance in an hasty manner, but by very slow degrees.



OF THE FIR.

*The different Degrees of Goodness in Fir Timber, how discoverable ;
the minute Vessels which enter into the Composition of this Tree de-
scribed at large.*

IN treating of the Oak I have considered, that the species of it growing in warm climates, is superior to that which is produced in cold countries. But we must not imagine this to be the case with all Woods ; on the contrary the Fir Timber growing in cold countries is superior to that produced in warm ones, where its growth is rapid. For the perpendicular vessels of which the Fir is composed are comparatively small, and though we may see here and there in this wood a large perpendicular vessel, that is no great exception to the general nature of it.

In the Fir, at the beginning of its growth every year, the perpendicular vessels, (which are all of the same kind), are formed twice as large as those towards the end of the season, when the growth ceases, and these latter-formed vessels are, in respect of their component woody parts, very compact and close, having very small cavities, and consequently producing durable timber ; and the less this tree grows every year, the greater number of these compact vessels enter into its composition. Hence we may gather, that if, upon examining Fir Timber at the ends, when it has been

cut or sawn across, we observe the circles, denoting each year's growth to approach very near together, we may easily conclude that such timber is firm and durable, especially if we perceive great part of these circles to be moistened or tinged with a resinous or gummy substance, named Turpentine.

The production or growth of the Fir is shewn in Plate I. *fig.* 7. which represents a small piece of this wood, as seen by the microscope, when cut transversely, in order to shew the difference between the perpendicular vessels formed in the Spring, and those produced in Autumn, when the growth ceases.

The natural size of the space contained between ABC, or EFG, is about the fifteenth part of an inch in length; ABFG, denote that portion of the wood formed towards the latter end of the year, and the line of separation appearing at BF, is the place where the increase for that year ceased. BCEF indicate a part of the same wood, produced in the beginning of the following year.

DD, and GG, are the horizontal vessels, which in this wood are placed very close to each other, so that when cut transversely it is difficult to distinguish them.

In this figure, we see the difference between the vessels formed at the beginning and at the end of each year's growth. And if the wood here represented, within the space ABC (which is the fifteenth part of an inch) required two years to enlarge the semidiameter of the tree to that thickness, it follows, that in this space there will be two rows or circles of the compact vessels pictured, between AB. Moreover, the piece of wood which is here described was from a tree of quick growth, and timber of slower growth not only would produce fewer of the large vessels, but also those vessels first formed in the spring would be smaller in proportion, especially if growing in a colder country, and in a good soil. In a word, the nearer the circles before mentioned approach together, the slower was the growth, and this species of Fir is the most durable.

In reflecting upon the nature of the tubes or vessels of which wood consists, I considered with myself, whether each of these tubes was not formed of two distinct kinds of excessively small vessels or coats, one sort extending lengthways, and the other sort encompassing each tube in a circular direction, as I had observed the quills* of feathers to be formed, in order to give to each tube a degree of strength and firmness.

To investigate this, I examined several kinds of wood, and particularly the Fir, and at length I observed in splitting the larger tubes or vessels of the wood, that some of them were indented or jagged in the splitting, and I also imagined that I saw the tube to consist of smaller vessels in a strait perpendicular direction which were not diffused all over the membrane or coat, but only placed on each side of it, whence I gathered, that though the minute vessels, some of which I conceived to extend longitudinally, and others to encompass each tube of the wood, cannot always by reason of their exceeding smallness be discovered, yet that the tubes are in reality formed like the quills of birds in order to give them the greater strength.

In further prosecuting this inquiry, I procured a piece of the Pitch Pine or Fir newly felled, and which had been of very quick growth; and having placed a small part of it before the microscope, I directed the Engraver to copy the figure of it as exactly as possible.

Fig. 8, ABCDEFG, represents this small piece of wood, which I split longitudinally as thin as possible. Its extreme thinness brought clearly into view a great number of globules contained in the vessels of this wood, and which afford a most pleasing spectacle, not only on account of their exact globular figure, but also because in each of the globules is a lucid or bright spot.

This small piece of wood I found particularly eligible for my

* The Author's examination of this subject will appear in the course of the work.

observations, partly because it is very rare to find a piece split out so long, and so thin with the perpendicular vessels so clearly discernible in it without obstruction to the sight from the horizontal ones, and partly because I have seldom found so many of the globules in so small a space. These globules in my opinion are the substance we call Turpentine, and from which, by burning the wood, Pitch and Tar are procured.*

Between DE and F, are to be seen the tubes of the wood when divided, which plainly appear to be split, not exactly strait in length, but in a manner indented or jagged and broken sideways.

I also put into the Engraver's hands two separate microscopes that he might make distinct drawings of these tubes of the wood, and from one of these was taken *fig. 9, M N*, where two of such tubes are represented when split lengthways; but the Engraver said that he could not possibly draw all the jagged parts which he saw. And we both of us perceived in the broken membrane or coat of the tube, many excessively minute vessels, which by reason of their smallness he was unable to express in the drawing. *Fig. 10, O P*, represents a single tube of the wood, in which, as plainly as could be done, is represented the broken parts of the membrane of which the tube is chiefly composed.

Since then we find by these observations, that the very fine membranes of which these woody tubes consist, is not always split lengthways, but often in an indented or jagged form, we may easily conceive that the tubes of wood, however minute they be, are partly formed similar to the quills of feathers.

* It is well known, that Turpentine is procured from the Fir, by making a wound or incision in the Tree, from whence the Turpentine flows in great abundance. This, upon being distilled produces the spirit of Turpentine, and what remains at the bottom of the still, is the substance called Rosin.—Pitch and Tar are obtained by burning large quantities of the billets of Fir, either in the open air, covered with fods to prevent evaporation as was the ancient practice, or in ovens constructed for that purpose, as is the modern method.

The fissure or splitting of the particle of wood, represented in *fig. 8*, was in such a direction that, as I may say, it passed or took its direction through the center of the tree, by which means the horizontal vessels, as well as the perpendicular ones, were divided longitudinally, and therefore are both exhibited in the same figure.

Between KI and HG, the horizontal tubes or vessels are represented when divided longitudinally. These vessels are found in great abundance in this wood, and in some places six, seven, or even twelve of them shall be found close together, and it is very rare to see so large a space of the perpendicular vessels without horizontal ones, as is between G and F in this figure, though the real size of that space is not more than the thickness of a large grain of sand.

I have often reflected on the nature of these horizontal vessels, that is, how they are formed, and how supplied with nutritive juices, for through them a new coat of bark is every year produced round the tree. At first, they undoubtedly have their rise from the marrow or pith in the center, but afterwards they must necessarily proceed from the ascending vessels. In this enquiry I could not fully satisfy myself, except that I observed the appearance of certain small dots or points in many parts of the perpendicular vessels, which at length I discovered to be no other than small round apertures. These are represented in *fig. 8*, between BC, and GH, and as I did not see them in any other places than where I had divided the horizontal from the ascending vessels, I concluded that at these small apertures the horizontal vessels are united to the perpendicular ones. And I began to consider whether the ascending tubes were not air vessels, as well as instrumental in conveying the nutritive juices.

I then sat about a more accurate examination of this wood, by cutting off thin slices with the sharpest edged tools I could procure, and placed them before the microscope, and hereupon I discovered a much larger number of ascending vessels than I had before

observed, which last discovered vessels were exceeding small in comparison of the former; so small, indeed, that if a large grain of sand were divided into ten millions of parts, these vessels would still be impervious to them. Hereupon I concluded that all the perpendicular vessels which I had before discovered in this wood, and through which I had supposed the juices for the nourishment of the tree, and its fruit, were conveyed, were really only air vessels; for those which I now name air vessels are surrounded with three or four of the very small vessels before mentioned. And I am clearly of opinion, that these minute vessels do constitute and form those others which I name air vessels, and connect them one with another; and that these smaller vessels convey all the nutritive substance for the support of the tree, its leaves and fruit, and that therefore they may properly be named arterial vessels.

The wood which in *fig. 8*, is represented split longitudinally, I now cut or divided transversely, to shew the nature of these vessels when inspected into or looked down upon, if I may so express myself; and at *fig. 11*, UVWYZ, a portion of it is represented as seen by the microscope, the natural size of which was no more than could be covered by a middling sized grain of sand; and in this figure, between the vessels composing the wood, or the air vessels before mentioned, are seen the very minute vessels which I call the arteries of the wood cut transversely; but as they are so very minute, I caused four of the air vessels to be drawn separate as viewed by a still deeper magnifier, that these last might be the better distinguished, and these are shewn at *fig. 12*, as they lie between the air vessels.

The dark streaks which are represented in *fig. 11*, at WYZ, are a small part of the horizontal vessels divided longitudinally, and which vessels are represented in *fig. 8*, between GH, and IK.

To this description I must add a little piece of the same wood which

I cut longitudinally, but in a different manner from that described in *fig. 8*; for as in that figure the wood is represented when so split that the air vessels, and those smaller ones which I call arteries, and also the horizontal tubes of the wood, are all divided longitudinally, here on the contrary the perpendicular vessels are split or divided longitudinally, but the horizontal ones are cut obliquely.

Fig. 13, L M N O, represents such a particle of the wood in which the horizontal vessels may be seen placed so close to each other as to be only separated by one or other of the air vessels. These horizontal vessels lying so closely and regularly beside each other it is no wonder that this kind of wood is of all, the most easily split, and strait in the splitting.

I have caused a separate drawing to be made of these horizontal tubes or vessels in their positions adjoining to each other, in order the better to distinguish how they lie among the perpendicular ones.

Fig. 14, P Q, represents these horizontal tubes or vessels, many of which are seen in *fig. 13*. These vessels in some places lie twice as close together as they do in others; and upon examining them with the greatest accuracy I was able, I must say that I saw two kinds of these horizontal vessels or tubes of the wood, one sort of which was so much smaller than the other as almost to escape the sight.

For the more fully elucidating this subject, and for the information of any who may have the curiosity to repeat my observations, I have in *fig. 15*, given a drawing of the manner in which I cut or split the wood. In this figure A B C D F, represents the fourth part of a round piece of the tree or a branch of it, of which B denotes the center of the tree or branch; at G is shewn how the particle of wood, represented in *fig. 8*, was split off; at C, how the particle represented in figures 11 and 12, was cut off, and at E, how the particle represented in *fig. 13*, was split off.

I have sometimes (as I before hinted) seen some of the perpendicular or ascending vessels in the fir, much larger in diameter than others; but these are so few, that it is very rare to observe them.

In *fig. 8*, between B and C, are to be seen the minute round apertures in those parts of the ascending tubes or air vessels, where the horizontal ones are seen, which apertures I conceive are destined to transmit air or the juices of the tree, from the ascending to the horizontal vessels.

These discoveries of mine, respecting the smallness or thinness of the vessels or tubes, composing the substance of trees, may not easily be credited by many, as not comprehending how, by reason of their exceeding smallness, any juice or liquor can possibly pass through them, and, what is more difficult to conceive, how through such vessels ascending perpendicularly, any nutritive substance can be derived from the root of the tree to the extremities of the upper branches.

But as, on the one hand, it is out of the reach of our finite capacities to comprehend the extent of the Universe;* so on the other, we are equally unable to conceive the minuteness of the vessels and component parts of which not only animals, but also vegetables are formed, and much less, how the parts of matter are united together, or how one part grows out of, or is added to, another.

* This sentiment is more fully expressed and largely dilated on, in the *Spectator*, No. 420, and many of the reasonings in that Paper seem to have been taken from the discoveries then newly made by our Author and his cotemporaries.



OF THE WEEVIL OR CORN-BEETLE.

Wherein the common opinion that this Insect is bred in Corn spontaneously, is shewn to be erroneous; the true nature of its Generation explained; with the means to preserve Corn from its infection.

I HAVE heard it strongly argued, that the Weevil or Corn-beetle, (which is a very noxious insect, well known to corn-dealers and bakers in this country,) is produced by what is called equivocal or spontaneous generation, that is to say, from inanimate substances without any parent. The principal reasons alledged in support of this opinion are, that we often find this insect in a new granary, where never wheat was kept before, and therefore it is deemed a necessary conclusion, that Weevils are not propagated by the ordinary course of generation. Again it is said, that we may open many grains of wheat, which are found and uninjured, so that no mark of a perforation or hole, shall be discernible on the outside, yet within these grains shall be found perfectly formed and living Weevils.

The answer which I have given to these arguments has been, that these little animals may, by ourselves, be removed from one granary to another without our knowledge: for supposing the person employed to remove corn, to have come out of a granary, or barn, infested with Weevils, he may easily carry some grains of corn containing them, or some of the insects themselves, sticking about his clothes, or in his shoes, and thus remove them into a granary where none

had ever been. Besides, the ship, waggon, or cart, employed to carry corn, may be infected with Weevils, by having carried grain in which they abound, and thus from a few of these insects, multitudes may be produced by the ordinary course of generation.

But in order fully to investigate the truth of this, I desired the persons who had argued this matter with me, to bring me the first Weevils they themselves should find, (it being then the winter season); and on the 13th of March, I received some grains of wheat, (many of which had the insides eaten away) mixed with Weevils.

I took three glasses, in each of which I put six, eight, or nine Weevils, and eight, ten, or twelve grains of wheat, which wheat I was the more assured could not be infected, because it had been kept for several months, closely covered up, in my study. In a fourth glass I put some Weevils without any wheat, but this last mode of experiment I afterwards rejected, observing that in the space of twelve days they all died. As to the other three glasses, the weather being cold, and, observing the animals, for the most part, to lie motionless, I put them into a leather case, which I always carried about me. And I had no doubt, but I should clearly prove to all, that the Weevil proceeds from a maggot, for which reason I frequently examined these objects by the microscope.

I, at first, entertained an opinion, that the Weevil, like the Silkworm's moth, and many other insects, did not, while in that shape, take any food: but herein I found myself mistaken, and observed that the Weevil not only feeds upon wheat, but that it can excavate or scoop out the whole contents of every grain, and creep about in the inside, being provided with a beak, or trunk of a great length, in proportion to the size of its body, at the extremity of which are certain exceedingly small organs, or instruments like teeth, and with these it can bore or pierce through the outward husk or shell of the wheat, and thus open to itself a passage to devour the contents.

At a fortnight's end, namely, on the 27th of March, I observed

some of these Weevils coupled together, and from this time I frequently inspected them, but saw no appearance of any living creature being produced from them until the 10th of June, when I observed lying among the Weevils and the wheat, two short and thick little maggots, one of them about the size of a large grain of sand, and the other about one fourth part larger: seeing this, I opened one of the glasses in which I had enclosed six Weevils, and examined the different grains of wheat that had been put in with them, and found two of them to be entirely hollow and empty; from another of the grains, which by the external appearance was the least eaten or consumed, but had many small perforations or little holes not discernible by the naked eye, I drew out a perfectly formed Weevil, which was of a yellow colour: whereas those which were at first brought to me, and had been shut up in the glass for three months, were of a deep red, almost approaching to black.

In another grain of the wheat I found a Weevil, of a very pale or white colour, with its claws, horns, and beak, or trunk, lying close to its body, in exact order, as we see the wings and legs of a Silk-worm's chrysalis or aurelia, when it is almost arrived at the state of a flying insect, only with this difference, that the unformed Weevil is not inclosed in a shell or case, like the aurelia of a silk worm.

In other grains of the wheat I found maggots of different sizes, and from one grain I took out a perfectly formed Weevil, whose white colour was changing to a red, and which was continually in motion.

Examining the other glasses, I found some of the grains of wheat perforated with little holes, and others half eaten. Some of the Weevils which had been shut up in these glasses I opened, and in one of the females, I found five white eggs, which I conceived to be of their full size: in others I observed eggs, some of which were arrived to maturity, and others gradually less and less.

Hence I concluded, that whereas the Silk-worm's moth, living

only a few days, in that time lays a multitude of eggs and then dies: on the contrary, the Weevil, which every day produces but few eggs, is a long lived animal, and by this means may be as prolific as Silk-worms or other insects: for the Weevils which I am now treating of were all alive the preceeding summer.

As to the two maggots which I at first found in the glafs among the wheat, I had no doubt that they had fallen out of the grains wherein they had been first deposited, by reason that those grains had been rather too much eaten away before the eggs were laid in them, and the holes which had been made in them rather too large; and, as all creatures, however minute, are endowed with most admirable faculties and powers to answer the ends of their creation, I think it very probable that the large trunk or beak with which this insect is provided, (furnished with teeth or pincers, which open and shut in exact correspondence with each other,) is given to it of such a length that it may be enabled to bore a small deep hole in every grain of wheat, and therein deposit an egg, otherwise the maggots breeding from these eggs would never grow to maturity: for if a Weevil were to lay its egg on the outside of a grain, and a maggot should be hatched from it, such a maggot could not possibly pierce the husk of the wheat. Again, were a Weevil to lay more than one egg in one grain, and all these eggs produced maggots, they would hinder each other's growth, for want of having sufficient nourishment, inasmuch as one grain is not more than sufficient to nourish one maggot, and so to produce one Weevil.

I observed in opening one grain in which a small hole had been made, and out of which I took one single egg, that round about that part where the egg was placed, the mealy substance of the wheat had been loosened or reduced to powder, from whence I concluded that the parent Weevil, before it laid the egg, had by means of its trunk, separated the particles of meal in that part, both to make a

soft place for the egg to lie in; and also, that when the minute maggot should creep out, it might find this soft and loosened meal prepared for its first feeding on.

Some of these maggots I placed in glasses by themselves, and observed them gradually to assume the form of Weevils, the beak, horns, and claws, appearing by degrees, and the colour also changing from a white to a yellow; and then to the red colour of the Weevil.

As I had observed, that none of these insects which were kept in glasses together with grains of wheat, ever deposited their eggs on the glass, I put three females into a glass by themselves, and in the space of twenty-four hours they laid four eggs. One of which eggs drawn from the microscope, is represented in Plate II. *fig. 1*, ABC. In the space of seven days these eggs produced the kind of maggots before mentioned, which, when first hatched, were not larger than a grain of sand, and one of these as lying on its back, and drawn from the microscope is represented at *fig. 2*, wherein DEF, is the head and FGD the body. This maggot was in continual motion, but when a little at rest, it contracted its body together, and in this position the limner drew its figure, and when it attained to its full size, the shape remained the same until the time approached for its being changed into a Weevil. Another maggot which I had fixed or fastened by its hind part before the microscope, I caused to be drawn when it extended its body, and this is shewn at *fig. 3*, HI K.

These maggots have very little strength to move from place to place, so that it seems designed by nature, that they should be fed no where but in grains of corn: for if a Weevil were to deposit its egg in any place, except in the inside of a grain, it would in my opinion, be impossible for the maggot thence produced to procure any nourishment and become a perfect Weevil.

These things considered, we may be fully satisfied respecting the

reason, why in corn, which is frequently moved and shifted, the Weevil can increase but little : for supposing one of these insects to have pierced and prepared two or three grains ready to deposit its eggs, and soon afterwards the corn is moved or spread about, the animal, when it is ready to lay an egg, finding no grain prepared to receive it, must leave such egg on the outside of the corn, where the young maggot, when hatched, will be in the same situation as seed sown in barren land, and consequently must perish. But if such corn is undisturbed, the Weevil may multiply, in a great degree, by depositing its eggs in the grains fitly prepared for them, and which may be considered as so many nests for the reception of the young. Again, the long life of this insect causes it to multiply exceedingly, for the Weevils which I received in the month of March, (the youngest of which was undoubtedly a year old,) were alive and vigorous in June following; and who can tell how long the natural life of this insect may be?

For the information of those who never saw a Weevil, one of these insects is represented of its natural size at *fig. 4, X*, and underneath it, I have given a drawing of its beak or trunk, as seen by the microscope, to shew by what organs or instruments this creature is enabled to pierce the corn, partly to feed on the contents, and partly to deposit its eggs in the small holes it makes therein : for, as other animals are taught by nature to prepare their nests for the reception and support of their young, so it is the peculiar instinct of the Weevil to aim at depositing its eggs in no other place than where the little animals produced from those eggs shall be able to find subsistence, and this is in the grains of corn.

At MNOP is represented the proboscis, trunk, or beak of the Weevil, which naturally is not so straight as here pictured, but appears bent downwards when seen sideways, as marked at MQO; but had the figure been drawn in that view, the opening at the ex-

tremity with its pincers or teeth would not have been visible, as it is now to be seen at O : within this mouth or orifice are two stings or piercers which are continually in motion and one of which is seen in the figure, but I never observed the animal to protrude or thrust those stings or piercers farther than the extremity of the pincers at O ; so that I imagine the only use of these organs is to break or divide the husks of the wheat and the meal within it ; and, having frequently contemplated this animal, while feeding, I observed it, after having thrust its trunk into a grain of wheat, to stick so closely to it, that, though tossed about, it would not let go its hold.

S T, are the two horns ; L M R, is part of the head ; and at M are represented* a collection of globules, which through the microscope exhibit the same appearance as if by the naked eye we were to see a parcel of very minute black coral beads placed in exact order close together ; and this I concluded to be one of the eyes.

I am not very fond of drawing the whole bodies of small animals from the microscope, because I consider that to be of little utility ; and this is the reason why I have only given a figure of part of this insect when magnified.

I trust that these experiments and observations will prove that Weevils cannot be produced, otherwise than by propagation, that is to say, by copulating and laying eggs, from which eggs maggots proceed ; and finally those maggots are changed into Weevils. But whether the vulgar will be hereby convinced of the error of their opinion in this respect, I much doubt, being continually pestered with their objections to what I have advanced. It is, however, with me, a most certain truth, that what I have demonstrated respecting the

* To those who have not been much conversant in these objects, it may seem strange that a collection of globules or little balls should constitute but one eye ; but such readers will be pleased to understand, that in most insects, each eye is formed of a great number of smaller optical organs, or eyes, and this subject will be found amply discussed in the course of this work.

Weevil, namely, that it cannot be produced otherwise than by generation, does also hold good with regard to all creatures endued with life and motion. And although this is a very minute animal, yet its species must have been continued in the way I have laid down, from its first being formed at the creation: and were it otherwise, namely, that from inanimate matter, such as stones, wood, earth, plants, or seeds, this or any other animal should be produced, that would be a departure from the general course of nature; and such formation or new creation, must be continually derived from the supreme Almighty Creator.

Probably what I here advance may appear strange to some, and they may perhaps wish me to enquire into the propagation of other minute animals; but for the present I leave the prosecution of these matters to those who may chuse to bestow as much labour thereon as I have done in this examination of the Weevil, assuring them that my observations are the result of more than four months application to the subject.



Of the Maggot or Caterpillar infesting Corn in Granaries; the nature of its generation explained, and the means to prevent its increase pointed out.

HAVING, as I hope, by my observations on the Weevil, convinced mankind, that it is propagated in the ordinary way of generation, I have since employed myself in the examination of that Insect or maggot which our bakers and corn dealers name "*de Wolf*."*

This creature is a very small white maggot, provided with two red pincers, or organs like teeth, placed in the fore part of its head, by which it not only feeds on, and consumes wheat, and other grain, but also can perforate or gnaw holes in wood. The common opinion is, that it is produced from corruption, or else from what some call a blight. But, in order to refute this vulgar error, I procured from a Merchant, a box of wheat, in which this insect abounded, that I might discover to all, the real manner of its propagation.

Upon inspecting this wheat, I found, that one single maggot had stuck or fastened together from five, to six, seven, or even eight, grains of wheat, in one of which itself was concealed, and that most of the other grains were hollowed or scooped out in the middle; and it seems to me that this maggot is much more pernicious than

* That is, in English, "the Wolf." This Insect is not much known in England among the country people, for the Translator having procured from an Importer of Corn, a sample of Prussian wheat infected with it, and shewn it to several farmers, the appearance seemed new to them, nor could they assign to the animal any name in English. But to the Dutch, who have always been great importers and exporters of corn, it seems to have been familiar, and the Author's remarks on this subject may be well worthy the attention of our English merchants.

the Weevil, because it scatters a great quantity of its excrements in the shape of white round balls, which are very large in proportion to the size of its body.

Moreover, this maggot has in the anterior, or fore part of its head, an organ, or instrument, through which it continually spins an exceeding fine thread, which thread it fixes to every substance it approaches. By this means its body is always supported so that it cannot fall, and in a clean glass it can move from place to place, being suspended by this thread, and by this thread also it connects or binds the grains of wheat together.

Some of this wheat I put into a glass tube, about the size of a finger, and a foot in length, closing each end with a good stopper, and the rest of the wheat I kept in a wooden box. But, towards the end of the summer, I observed several of the maggots forsaking the wheat, and fastening themselves to the glass, and others of them I saw creeping about among my papers, and I found the box, in which I had put them, perforated in two places, through which many of them had escaped. I also saw the stopper to the glass tube gnawed into, as deep as the thickness of a finger, and upon taking it out, I found that eight or ten of the maggots had crept into it; upon which I placed them again in the glass tube, with the grains of wheat, and stopping the orifices with a cork, I covered the cork on the outside with sealing-wax, to prevent the maggots again escaping, but at the same time I contrived a small aperture that they might not be deprived of air. Plate II. *fig. 5*, ABCD represents this glass tube, of which AD, and BC are the two extremities, each closed with a stopper covered with sealing-wax; EG and FH are two small glass tubes, passed through the stoppers, to supply the maggots with fresh air, but those apertures were so small as not to permit their escape.

About the same time that I was employed in these observations, I visited a granary infested with this insect, and saw the maggots, in great numbers, creeping up the walls, from whence I concluded,

that in like manner as the maggots in the glass tube quitted the wheat, and lodged themselves in the stoppers, so in the granary they concealed themselves in the linings and beams, until their transformation into flying insects should be completed. And I was confirmed in this opinion by observing the granary to have been so perforated, or eaten into by these maggots, that not a finger's breadth was left untouched by them.

I also observed that great part of the stopper which was within the glass tube, was gnawed or reduced to powder, and many chinks or crannies formed in it, and though the maggots endeavoured to conceal themselves within the stopper, yet three of them remained in the glass, in which they lay quiet the whole winter, and they were so little covered with their web or thread, that, with the microscope, I could discover them move their heads.

On the 29th of April following, I saw them begin to assume a reddish colour, and to be somewhat contracted in length; the next day the redness increased, and they seemed to me to be turned into aurelias.

At the same time, upon examining the wheat, which was kept in the box, and had been full of the maggots, I found that they had all escaped through the holes perforated by them in the box.

On the 23d of May, the aurelias before mentioned, had become of a red colour, and the next day I saw a flying insect, which is called a Moth, fluttering about the glass tube. This had proceeded from one of the aurelias, which had been the chief subject of my observations, and I saw lying near it, a pellicle, or little skin, which had been the case or sheath in its aurelia state.

Two days before discovering this moth, I had observed several of the same winged insects flying about my study, two of which I killed, and upon examining them by the microscope, I found them to be formed in the same manner with this in the glass, so that I was convinced they had proceed from some of the maggots which had escaped

out of the box. And on the 25th of May I saw two more moths come out of the stopper to the tube, leaving their shells or cases hanging to it.

As many persons are unacquainted with the figure of these moths, I have caused a drawing to be made of them, which is to be seen at *fig. 6, A A*; and also a drawing of the covering, shell or case which encloses them while in their aurelia state, *fig. 7, P Q*. These figures were drawn of the natural size, and if I had not had ocular proof of it, I could not have believed it possible for the moths to come out of so small a case or covering as is here pictured. *

On the same 25th of May, I went to the granary, where, the preceding autumn I had seen the maggots before mentioned creeping up the walls, and there I saw a number of moths, some clinging to the wall, and others flying about. I had brought with me six glass tubes, and, as it was easy to distinguish the males from the females, the former being smaller than the latter, I put in each of these glasses some of both sexes.

At my return home, I dissected three of these females, and, by the most accurate reckoning I could make, I found in each of their bodies upwards of fifty eggs. At another time, I judged that I took out of another female moth, above seventy eggs. These eggs were exactly the shape of hens eggs, but no larger than small grains of sand. The rest of the moths which I had brought from this granary and kept alive, laid many eggs, and one of them produced to the number of seventy.

I next considered, whether the moths, which thus propagate the

* This observation of the Author is corroborated, and, at the same time, the appearance can be accounted for, by a circumstance which was some years ago communicated to the translator by a curious observer of the change of aurelias into butterflies and moths, namely, that immediately after their emerging from the shell, or covering, which incloses them, they increase in size so rapidly, particularly in the wings, that their growth may be discerned by the eye.

pernicious insect I am treating of, might not, by some means, be destroyed in the granaries, so as to prevent their propagation.

For this purpose I took a round glass vessel, large enough, as I supposed, to hold six pints of water, and in it I put eight living moths newly taken. In the orifice of this vessel I set fire to the fourth part of a grain of sulphur, and as soon as the moths began to feel the vapour, or smoke of the sulphur, they fluttered about the glass with great violence, though but for a short time, for they all fell to the bottom, and after a little motion in their feet, they died. Four hours afterwards, I took them out of the glass, and put into it some fresh ones alive, in order to repeat the experiment, but while I was preparing to burn the sulphur, I saw them all lie dead, they having been killed with the bare odour of the sulphur which had been left in the glass.

From the size of this glass, I computed what quantity of sulphur would be requisite to fumigate a granary twenty four feet long, sixteen broad, and eight feet high, and I reckoned that half a pound would be sufficient for the purpose.

After this, I fumigated a granary, in which were eight loads of wheat, and a great number of moths flying about. For this purpose I took two pieces of sulphur, containing about a quarter of a pound, prepared in the same manner as is done by wine-merchants or coopers, to fumigate their wine casks. These pieces of sulphur I suspended by a brass wire, in a tall earthen vessel, with a narrow top, and placed the vessel in an earthen dish, to prevent any danger of fire. This apparatus I set in the middle of the wheat, and as soon as the sulphur began to burn, I retired out of the granary and shut the door. In a large granary two or three of these vessels might be used.

Two days afterwards, I visited the granary, and then I saw several moths still clinging to the wall and beams, but before the fumigation, I believe there were ten times as many. And I accounted for these moths being found alive, either because many of the panes of

glafs in the windows were broken, through which much of the fmoke of the fulphur had efaped, or elfe, that the moths which I now faw, had come out of their aurelia ftate after the fumigation was over; for I am well affured, that fo long as the moths are inclofed in their aurelia cafe, or covering, the fmoke of fulphur cannot do them any injury. Therefore it will be neceffary for thofe who may chufe to fumigate their granaries in the manner I have recommended, to begin the operation as foon as ever the moths appear, that they may be prevented laying their eggs, and alfo to continue the ufe of it fome days, indeed as long as any moths are to be feen, becaufe thefe creatures do not all come out of their aurelia ftate at the fame time. The expence of fumigating is no object, for a pound of fulphur may be bought for a trifle, and it is in no fort injurious to the wheat, nor is it prejudicial to the health of any perfon, but rather falubrious.*

Towards the end of fummer, when the maggots quit the wheat, and creep up the walls, they may eafily be fwep down and deftroyed, for this infect is a very tender animal, and foon killed. And thefe precautions being obferved, very few moths will be feen the following year.

Some of the eggs laid by thefe moths I put in glaffes by themfelves, which I carried about in my pocket, others of them I placed in my ftudy, and I obferved that thofe which I carried about me were, by the heat of my body, much fooner hatched than thofe which were in my ftudy, for thefe latter were fixteen days before the maggots crept out of them; but at feven days end thofe in the former made their appearance.

One of thefe maggots, when newly hatched, I put into a glafs tube, the infide of which was about the fifth part of an inch wide, and having placed this before the microfcope, I gave it to the limner

* This opinion is confirmed by Dr. Hodges, and Dr. Mead, in their Treatifes on the Plague.

to make a drawing of, but as it was impossible for him to draw all the minute parts of it, he drew it without the feet, as is shewn in *fig. 8*, K L.* The fore part of this maggot is provided with six feet, which sometimes could be discerned when the animal lay flat on its belly, and these, with part of the body are shewn at *fig. 9*, M N. In the hind part are various organs assisting in its motion. This maggot, although, when newly hatched it appeared no longer to the naked eye than is described in the center of the circle at *fig. 10*, was yet twice the length of the egg from which it was produced.

As I observed some of these young maggots to be dying, I put some grains of wheat into the glass, and soon afterwards the living ones disappeared, whence I concluded that they had found their way into the wheat, and in three or four days time I saw their excrements scattered about the glass.

I have often contemplated the shells of the eggs from whence these maggots proceeded, and observed vessels in them in the nature of net-work, which I could not distinguish while the eggs were full. A drawing of one of these is given at *fig. 11*, R S T V, but as these eggs are exceedingly minute, this drawing was made from a microscope of greater magnifying power than that from which the former figures are drawn. S T V is the broken shell of the egg in the part where the young maggot crept out.

The moths I have been describing are very pretty objects to behold, the wings, which are four in number, being white, sprinkled all over with black spots; and on examining them by the microscope I found that this whiteness proceeded from the white feathers on the wings, and that the black spots were caused by other feathers which were black at the edges. Some thousands of these feathers

* This figure does not seem taken with so much exactness as is generally found in those given by Mr. Læwenhoek, therefore the Translator has caused a drawing from one of the maggots when full grown, to be made of the same size it appears to the naked eye, and this is to be seen at *fig. 12*.

I saw sticking to the glasses in which I kept the moths, which in their fluttering against the glass or one another, had been rubbed off their wings and other parts of their bodies; and to the naked eye, exhibited the appearance of a vapour or smoke on the glass.

Though I examined some thousands of these feathers, they were all so differently formed, that I cannot say I saw two exactly alike. *Fig 13*, A B, C D, E F, represents three of the largest of them, when seen through the microscope. At their broad ends, they are tinged with black, and when several of them lie close together, they exhibit a black spot. Others of these feathers, as *fig. 14*, G H, I K, L M, are transparent, but when lying one on another they produce the whiteness I have mentioned. All of them, although so very minute, have quills like the feathers of birds, by which they are fixed or rooted in the membrane that forms the wing, and so completely cover it that it cannot be seen.

The feathers, which cover the edges of the wings, are much longer than the others, and of different shapes; five of them are represented at *fig. 15*, R S, T V W, and at *fig. 16*, N O P Q, are shewn a number of the small feathers of different shapes.

This maggot, which among us is called the wolf, is not only mischievous, by devouring the corn, but it is of that species which is found in houses, and gnaws holes in wood, also in boxes and books, and likewise hides itself in woollen garments, eating holes in them, and at length becomes a flying insect, named as before mentioned, a moth.

This moth, of itself, is very innocent, for while in that state, it does not, as I could discover, take any food, but, if not destroyed in time, one female may produce seventy maggots, for out of upwards of seventy eggs, laid by one moth, I only saw one barren; and in three others of the eggs, I could discern the maggots lying dead, by reason, as I suppose, that they could not break their shells.

I heard it affirmed, by a corn-dealer, in support of his opinion,

that these maggots are produced in wheat spontaneously, that they are more rarely found in old wheat than in new; to which I gave for answer, that when first hatched, they are very small and tender, so that it is difficult for them to pierce the husk of old wheat, the same being very dry and hard, and consequently many of them die for want of nourishment. This I fully proved by experiment, for I had three glasses standing in my study, in one of which there were more than sixty maggots newly hatched. In this glass I put some grains of wheat, one of which was broken, or split down the middle, and this alone was eaten into, the others remaining uninjured, and all the maggots, except one or two, died; all which, I had no doubt, proceeded from this, that these grains of wheat were remarkably dry and hard, having been kept for two or three years in a box in my study: and in another of the glasses, wherein I observed the maggots creeping about on the surface of the wheat, without being able to penetrate it, I cut several of the grains in pieces, and by this means many of the maggots were kept alive.

Towards the end of the month of September, I received from a baker a handful of very excellent rye, with many of these maggots in it, all which I put into a large glass vessel, and I observed the maggots quit the rye and creep up the sides of the vessel. I then burnt a small quantity of sulphur in it, and in a short time they were all killed.

It may not here be unworthy of notice, that, in the glass tube before described, and in which I imagined I had put nothing except wheat, and the caterpillar or maggot, of which I have been treating, I found a Weevil make its appearance: this creature I kept in the glass to see if any more would appear, and I observed, that in the winter or in cold weather it lay motionless as dead, but upon applying some warmth, it would revive. At length, after keeping it upwards of eighteen months, in which time, I did not observe any more of the species, it died.

Moreover, while I was examining the granary before mentioned, I saw many very minute animalcules*, no bigger than grains of sand, creeping up the walls. Some of these I brought home with me in glasses, and I observed them to couple together, and to lay excessively minute eggs, which eggs, after some time, produced animalcules formed like the parents. By this it appears that these little creatures propagate their like, without undergoing any such change as is observed in fleas, moths, flies, and many other insects: I think, however, it is fully proved, that no living creature is produced from corruption or putrefaction.

Indeed, can any man in his sober senses imagine, that the moth, of which I have given the description, which is fitly provided by nature with the means to propagate its species, furnished with eyes exquisitely formed, with horns, with tufts of feathers on its head, with wings covered with such multitudes of feathers, all of different shapes, and these exactly covering the wings in every part; can this moth, I say, adorned with so many beauties, be produced from corruption? For, in a word, in this little creature, contemptible as it seems to us, there shine forth so much perfection and skill in the formation, as to exceed what we observe in larger animals.

* Mr. Leeuwenhoek has not given any figure of these animalcules, but they seem to be a species of mite; the translator has observed some of the like kind in bran.



(82)

OF THE SPIDER.

THE following observations were made on those kinds of Spiders which are found in gardens ; where they fix their webs to vines, herbs, and shrubs.

I have often seen these Spiders, when dropping, or falling, as it seemed, from a tree, stop or support themselves in the midway, by means of their thread, and I found that this was done by the help of one of their hind feet, which they continually apply to the thread as they spin it. These feet are each of them furnished with three nails or claws, standing separate, or apart from each other. Two of these claws are at the extremity of the foot, and each of them is formed with teeth, or notches, like the cuts in a saw, growing narrower towards the bottom ; and with these they are enabled to hold fast the thread, in like manner as the pulley or wheel, used by clock-makers, in their thirty-hour clocks, is contrived to lay hold of the clock-line, by means of the groove being narrower at bottom. For the more perfectly understanding this formation, I caused the following figure to be drawn.

Plate II. *fig.* 17, A B C D E F, represents a small part of the Spider's hind foot, magnified, and at B C D, are shewn the two claws, or nails, with the notches or teeth in them, as before described : at letter E, is seen the third claw, which is destitute of teeth or notches, but, as I conceive, serves for various uses to the animal, and this is always to be noted, that when the Spider does not want to ascend to an height, but only to lay hold of the web it has spun, it always uses this claw for that purpose.

The kind of Spider I am now describing, has the hind part of its body much larger than is seen in other Spiders ; it is provided with eight longer and two shorter legs, which shorter ones are placed in the fore part of its body on each side of the head, and all furnished with an indented or notched claw as before described. Some will have it, that Spiders have no more than eight legs, but this appears to be a mistaken opinion.

In these Spiders I plainly perceived eight eyes, two of which are placed near to each other at the top of the head, and, in my judgment, designed to see those objects which are above the animal. Two others of them are situated a little lower down, in order to discover all objects in front ; and on each side of the head are a pair of eyes close to each other, and of these, the two which stand forward, are to take in the view of all objects lying obliquely, or not straight in front ; and the two which stand backward, are undoubtedly designed to behold all objects behind the animal. And if we consider that the pupils of these eyes are immoveable in the head, we may easily conclude, that this number is necessary, for enabling the Spider to behold all circumjacent objects, and to go in search of its food.

That the form of these eight eyes, and their situation, may be more easily conceived, I have caused a drawing to be made of them at *fig. 18*, GHIKLMNO, which represents a part of the Spider's head ; P Q, are the two eyes which look upwards, K and L, the two designed to view objects in front, I and M, those which take in objects obliquely in front, and H and N those which look obliquely backwards.

I have often heard it said, that the Spider has a sting, with which, it is also reported, it can kill the toad ; but no one could tell me in what part of the body this sting was placed, therefore, I concluded that if there was one, it must be in the posterior or hind part, as in other animals and insects ; but on examination, I found this opinion to be groundless. The Spider is, however, provided with two

organs or weapons answering every purpose of a sting, which are placed in front of its head just below the eyes, and when not in use, they lie between the two shorter feet.

These weapons or instruments of offence, which are bent in the nature of claws, are very similar to the sting of the Scorpion and the fangs of the *Millepeda of India, and in each of these fangs (for so I will call them) is a small aperture, through which, in all probability, a liquid poison is emitted by the Spider at the time it inflicts the wound.

At *fig. 19*, ABCDEFGHIKLM, are represented both these fangs as seen through the microscope: BC, is one of them when lying still, HIK shews the other, raised to strike. At C and I, is to be seen the small aperture† I have mentioned, which aperture appears the same on both sides of each fang, and through this we may reasonably conclude that the Spider ejects its venom. At the letters EFG, is a double row of teeth, between which each fang is placed when at rest, and the use of these teeth seems to me to be for the firmer grasping the prey, that when bitten it may not escape. All the other parts of these weapons or organs which are represented in *fig. 19*, were thick set with hairs, but which it was not thought necessary to exhibit in the drawing.

I at several times inclosed two or three large Spiders in the same glass, and always found that when they approached each other, they

* That is in English, thousand legs, the name vulgarly given to this animal; the Dutch call it Duyfent-been, a word of the same import.

† Dr. Mead, in his celebrated Essay on Poisons, when treating of the Spider, expressed his doubt of this fact, by reason that he could not himself discover the aperture, and Mr. Henry Baker, in his Treatise on the Microscope, concurred in opinion with the Doctor, that Mr. Leeuwenhoek must have been mistaken in this particular. But in another Treatise*, afterwards published by Mr. Baker, he informs his readers, that he had at length plainly perceived the aperture, and had shewn the same to Dr. Mead, who was much pleased with the discovery. A testimony this, greatly to the honour of our Author.

* Employment for the Microscope.

would fight to that degree, as to be covered with the effusion of blood from their bodies*, which was soon followed by the death of the wounded Spider. I also observed, that the smaller Spiders always avoided the larger, but when two of nearly equal size approached each other, neither would give way, but both of them grappled together furiously with their fangs, till one of them lay dead upon the spot, its body being as wet with the blood flowing from the wounds received, as if water had been poured upon it.

I at one time had a Spider which was wounded by the bite of another in the thickest part of its leg, and from the wound there issued some blood, in quantity, about the size of a large grain of sand; this wounded leg, the Spider held up, as unable to use it, and soon afterwards the whole leg dropped from its body: whenever the breast or fore part of the Spider was wounded, I always observed the wound to be mortal.

I had imagined, that when a Spider applied its thread either to some foreign substance or to another thread, that the thread newly spun must be covered with some viscous or glutinous matter by which it became fastened, in like manner as we observe in Silk-worms threads. But I now found that the Spider cannot fix its thread to any thing, without imprinting the hind part of its body on the place, by which pressure, it emits an incredible number of excessively small threads, diverging in every direction, from whence we may conclude, that as soon as the threads are exposed to the air, they lose their viscosity or glewy quality.

When I at first began the dissection of the Spider, and endeavoured to discover the viscous or gummy substance from whence these threads proceed, and could not satisfy myself in that particular, I was astonished, not being able to conceive how, from so moist a

* If any reader should be disposed to try this experiment, he must not expect to see a red liquor issue from the wounded Spider. For the circulating fluid in many insects is clear or colourless, though as fitly to be denominated blood, as that which flows in the veins of animals.

body as this creature's, there could in so short a time, be produced threads strong enough to bear the weight, not only of one, but of six Spiders at a time. And upon endeavouring to discover the texture of the threads, I could at that time perceive no more, than that the same thread appeared in some places to be one and entire, and in others, to be composed of three, four, or more threads; and though I often endeavoured to observe those threads immediately as they issued from the Spider's body, I could not obtain a perfect view of them, notwithstanding which, I did not doubt, that what is commonly supposed to be one thread, is, in fact, composed of many.

I determined therefore, so to fix a Spider on its back, that it could not move the hind part of its body; and this being done, I contrived with a small pair of pincers to draw out from the body, that small part of the thread which projected from the organ or instrument from which the threads proceed, and then I perceived a great number of exceeding small threads issue forth, which, when at about one or two hairs breadth distance from the Spider's body, united in one or two threads, and that in this manner the larger threads were composed.

Not content with these observations, I sat about devising means of keeping the threads separate, as they issue from the Spider's body, so that I might be able to give some representation of their inconceivable fineness, and at three several times I succeeded herein to my wish. But yet, this fineness cannot by any efforts of the pen or pencil, be adequately described. For upon applying the utmost magnifying powers of the microscope, threads are discovered so exquisitely slender, as almost entirely to escape the sight. I have sometimes endeavoured to count these threads as they issued forth, but always without success.

The Limner, to whom I exhibited this object by the microscope, declared, that it was not in his power to give a true drawing of it

with the pencil, but that by an engraving, it might in some measure be represented. This is done in *fig. 20*, MNO PQ, being a portion of these threads, as magnified by the microscope, and pictured separate and distinct from each other, as they issued from the body of the animal. These seemed to me to issue from two of the organs, which I shall presently describe.

If we duly consider that the threads of Spiders, which to the naked eye seem to be single, are composed of many smaller ones, and that they thence acquire the strength we observe them to have, we shall more than ever be assured, that no flexible bodies (except those made of metal, the component particles of which are, by the force of fire, most closely compacted or knit together), can have any great strength or toughness, unless they are composed of oblong parts laid side by side, and that their strength or toughness will be greater where these oblong component parts are twisted together, or made to cohere by some glutinous matter, as are spun silk, linen garments, ropes and the like. And this is the reason why all the single threads of flax are very tough in proportion to their size, for each of them is composed of still smaller particles or fibres, which are not only joined together by a certain viscid or gummy matter, but are also surrounded with a coat or bark, as it may be called, whereby their inward component fibres are rendered still stronger.

Again, if we advert to the great number of excessively slender threads, proceeding, all at the same time from the body of the Spider, we must acknowledge that this kind of formation is necessary, for were it a single thread which is spun by this creature with such celerity, the liquid matter of which it is formed, could not on its exposure to the air, become a solid substance so quickly as these lesser threads; an hundred or more of which, taken together, do not in my opinion equal the hundredth part of one of those hairs I can take from the back of my hand.

In a word, the inscrutable power and wisdom of the Almighty Creator, are manifestly displayed in the formation of such a thread as the Spider's, the wonderful make of which is seldom observed, because the fineness and delicacy of its texture are not discernible by the naked eye.

Upon beholding the exquisite slenderness, and also the multitude of these threads, I was struck with astonishment, upon considering how wonderful must be the organs in a Spider's body to produce so many, and at the same time all distinct from each other. And although I never expected that I should be able to dive into this secret of Nature, yet, upon dissecting the hind part of one of the largest Spiders I could procure, and attentively examining it, I at length, with the greatest admiration, perceived a great number of excessively small organs, from each of which, one exquisitely fine thread proceeded, and these were so many, that I thought their number must at least exceed four hundred. They were not all placed close together, but in eight distinct spots or compartments, so that if the Spider uses all these organs at the same time, eight several threads may be formed, each of which will consist of a great number of smaller ones. Again, these smaller threads differ in size, for one of the organs will be seen to spin a thread twice as large as the next adjoining to it.

If any person examines by the microscope that part towards the extremity of the Spider's body, from whence its thread proceeds, he will observe the spot to be, as it were, surrounded by five several protuberances or risings, each ending in a point, and altogether forming a kind of enclosure; but from the anterior or forwardest of these five protuberances no threads proceed. The other four, on their outer sides are thick set with hairs, so that all the smaller organs destined to spin the threads, are situated towards the inside, the reason of which, I take to be, that they may be preserved uninjured,

when the Spider is creeping into holes, where it does not want to spin its web, or while running along the ground, or after its prey. When these last mentioned four protuberances are put aside from each other, there will be seen in the middle or space between them four smaller ones, each furnished with the like organs for spinning threads, but lesser in size and fewer in number.

These organs for spinning, being by this means all exposed to view, exhibit the appearance, as it were, of a field, thick set with an incredible number of pointed parts, each producing one thread; but these pointed parts are not made gradually tapering from the base to the point; they are formed, as if one were to imagine a small reed somewhat tapering, having a still smaller one joined to its taper end*, and this latter terminating in a point, which point, in these organs I am now describing, is as fine as imagination can conceive.

Now if we lay it down as a fact, that a young Spider which is several hundred times smaller than a full grown one, is furnished with the same organs as the larger, and that, as the Spider, so the organs do by degrees grow proportionably larger, the necessary conclusion is, that the threads spun by a young Spider, are many hundred times finer than those spun by one full grown, which exquisite slenderness, it seems beyond the power of the human mind to form a true idea of.

I have given a representation of some of the organs, by which these incredibly small and numerous threads are spun, as nearly as the Limner was able to draw them, when seen by the microscope. And, at *fig. 21*, RSTV, exhibits one of the four external parts or protuberances I have been describing; this part, including all which with it is represented in the figure, was not in its natural size so large as a common grain of sand, from whence some judgment may be formed how minute must be these organs, and how exquisitely fine the threads which issue from them.

* See *fig. 22.*

In this figure, that part which is marked with the letter W, was covered with as many organs, and those placed as close together, as are represented between the letters R and S, but as these latter, standing directly in front, could not by any means be distinctly shewn in the drawing, I ordered that space to be left vacant: the part which is out of sight, was not covered with these organs but with hairs.

While I held this object up to the Limner's view, I turned round the different parts of it, that he might declare how many of the organs for spinning the threads, in his judgment, it contained, upon the view of which, he was confident that there were above one hundred.

I have before mentioned, that some of these organs appeared to me to be larger than others, and that I supposed their use was for spinning the larger threads. One of these, as it stood between two smaller ones, I placed in view of the Limner, directing him to make a drawing of it. This is seen at *fig. 22*, C F., and in the same figure, at the letters AB and DE, are represented the two lesser organs, from one of which, a thread is seen to issue.

After this, I took a small Frog, whose body was about an inch and an half in length, which I put into a glass tube together with a large Spider, in order to see the actions of these two animals when brought together; and I observed the Spider pass over the Frog without hurting it, though with its fangs displayed as if to attack the Frog. Upon this, I caused the Frog to fall against the Spider, who, thereupon, struck his fangs into the Frog's back, making two wounds, one of which exhibited a red mark, and the other a purple spot. I then brought the Frog to the Spider a second time, who, thereupon, struck his fangs into one of the Frog's fore feet, whereby some few of the blood vessels were wounded. And having provoked the Spider a third time, he struck both fangs into the Frog's nose,

presently after which, I took the Spider out of the glass. The Frog, thus wounded, sat without motion, and in about the space of half an hour, it stretched out its hind legs and expired.

The next day I brought another Frog, about the same size as the former, to the same Spider, but though it was twice wounded, I did not perceive it to be injured thereby, perhaps because the Spider's bite may not be so venomous in our climate as in warmer regions, or else, that the poison of this Spider might have been exhausted by former attacks; the Frog I threw back into the water whence I had taken it.

Towards the end of October, I took several of the largest Spiders that could be got, and placed them in glasses apart by themselves, in order to wait for their laying eggs, which I purposed to open, and examine the contents. Two of these Spiders, after being confined ten or twelve days, I found had laid their eggs, and enveloped them in so thick a web, that I was astonished to behold it, considering that it had been spun in a few hours space.

Some of these eggs I opened, and found the insides to be of a yellowish colour; the form of each egg was almost round, and nearly the thirtieth part of an inch in diameter, and the whole collection of eggs laid by one Spider composed a rounding figure, almost spherical, nearly half an inch in diameter, from whence may be computed how great a number of eggs the Spider lays. And one would almost think it impossible for so many to be contained within this creature's body; since upon viewing them with the naked eye, as they lie together in regular order, they occupy a larger space than the size of the animal itself. But it must be considered, and it is what I have often experienced in opening Spiders, that the eggs while within their bodies are not of a globular figure, but being very soft they lie compressed together, and therefore are of divers shapes, but as soon as emitted from the Spider they assume a spherical form, by

reason of the equal pressure of the atmosphere on every part of them ; and when of this round figure, being placed in exact order, side by side, and only touching each other in a point, they must necessarily, to our view, occupy more space than they did while in the animal's body.

I at first was not able to conceive by what means the Spider could place its eggs so exactly in the centre of the web, but now I was satisfied in that particular, for while I was observing a third Spider which was fixing a web to the glass in order to lay her eggs in it, I saw that first she made a kind of thick layer of threads, and fastened them to the glass before she began to lay one egg ; and it was most worthy of remark that this layer or stratum was not flat, but curiously made with a roundish cavity. In about three quarters of an hour's space, upon again observing the Spider, I saw that this cavity was not only filled with eggs, but that eggs were piled up above the edges of it to the same height as the hollow of the cavity below, and the Spider was then busied in spinning a web to enclose the eggs on every side. For this purpose she employed not only the hind part of her body from whence the threads were spun, but her two hinder feet, with which she placed the threads in due order. And now all the organs used in producing the threads appeared in view, each of them in the act of emitting its particular thread. I also observed the Spider elevate the hind part of its body about the breadth of a straw, and then fix the thread which by the elevation had been drawn out to that length, to the web which was already spun about the eggs.

I was very desirous to see a Spider in the act of laying its eggs, which at length I obtained a sight of, and observed that they were not emitted from the same part as is usual in all other minute animals ; but from the fore part of its belly, not far from the hind legs, and near the place, I observed a kind of little hooked organ, handsomely shaped, which I had often before seen in this animal, and

could not imagine for what purpose it was designed ; but now I perceived, that it extended over that part whence the eggs issued, and I therefore conjectured that its use was to deposit them in regular order within the web prepared to receive them. To give some representation of these parts, I caused a drawing to be made of a middling sized Spider, lying flat on its back, with the legs contracted, as if it were dead. This is shewn in *fig. 23*, ABC, and near to letter D is the hook just mentioned.

This hook I then separated from the Spider's body, and placing it before the microscope I delivered it to the limner, that he might make a drawing of it as it appeared to him. This drawing is given at *fig. 24*, GHIK, and therein between the letters I and K, certain folds or wrinkles appear, this organ being so formed as to have a greater extent of motion and action than usual. The letters EF denote that part which was joined to the Spider's body.

On the first of January, I put some Spider's eggs into a glass tube which I constantly carried about me, in order to discover whether by the warmth I imparted to them, they would be hatched sooner than the usual time, which is in the spring ; and on the 17th of January I saw above twenty five young Spiders compleatly hatched, and as many more half way out of the eggs ; and in the evening of the same day I counted above an hundred and fifty young ones. The next day, the number was not increased, for the remainder of the eggs, to the number of fifty, or thereabouts, were either barren, or the young Spiders were dead within them.

Upon exposing the glass tube at this cold season, to the air for about a quarter of an hour, the young Spiders lay without motion, but upon applying some warmth to it, they began to move, and the greater number of them crowded themselves together in an heap, after the manner of bees, within the web where the eggs had been. On the 21st of January I could discern eight eyes in each of them,

which till then had not been visible, and on the 25th of January they began to spin webs in the same manner as full grown spiders.

I had hitherto been at a loss to conceive how this great number of young Spiders could be supplied with nourishment, considering that the natural food of this creature is the substance of other insects; but I now perceived that they had fed on the barren eggs which had been left in the glass, and they afterwards devoured one another till they were reduced to a very few in number.

I have often compared the size of the thread spun by full grown Spiders with a hair of my beard. For this purpose I placed the thickest part of the hair before the microscope, and from the most accurate judgment I could form, more than an hundred of such threads placed side by side could not equal the diameter of one such hair. If then we suppose such an hair to be of a round form, it follows that ten thousand of the threads spun by the full grown Spiders when taken together, will not be equal in substance to the size of a single hair.*

To this if we add that four† hundred young Spiders at the time

* This is found by multiplying the number of Spiders' threads, constituting the diameter of the hair (which the Author computes to be one hundred) into itself, the contents of cylinders (which round threads may be called), being in the same proportion as the squares of their diameters—

	therefore	100	diameters of the thread
multiplied by the same number		100	
the square will be		10,000	the proportionate size of the hair,
and this being multiplied by		400	the supposed bulk of a young Spider com-
		4,000,000	

pared with an old one, gives four millions, the proportion assigned by the Author to the young Spiders' threads.

The Author's manner of computing these very minute dimensions, is fully explained in the Introduction.

† The difference in the size of garden Spiders in Spring and Autumn, must have been noticed by almost every one, and the Author in his computation, considers them as spheri-

when they begin to spin their webs, are not larger than a full grown one, and that each of these minute Spiders possesses the same organs as the larger ones, it follows, that the exceeding small threads spun by these little creatures, must be still four hundred times slenderer, and consequently that four millions of these minute Spiders' threads cannot equal in substance the size of a single hair. And if we farther consider of how many filaments or parts each of these threads consists, to compose the size we have been computing, we are compelled to cry out, O what incredible minuteness is here ! and how little do we know of the works of Nature !

I never could procure a fight of these animals when coupling together, either in the gardens or fields, nor when inclosed in glasses, for I always perceived the female to run away at the approach of the male, and having at one time inclosed three male Spiders with a female in one glass, the female flew at the males with so much fury, and wounded them to such a degree, that blood issued from their legs and feet. Hereupon I killed the female, and the next day I saw two of the males lie dead, and the survivor employed in devouring the dead female.

These are the chief of my observations on the Spider, an animal held in such detestation by many, that they dread even the sight or approach of it, but in which we find as much perfection and beauty as in any other animal.

cal bodies, which according to the rules of arithmetic, are in the same proportion to each other as the cubes of their respective diameters. Thus, if a young Spider's body is a seventh part of the diameter of a full grown one, the latter will be 343 times the bulk of the former, if an eighth part, 512 times. The proportion here assigned by the author, is nearly the medium between these two.



(53)

OF THE SILK WORM.

THE Royal Society having recommended to my examination, the fruitful and barren eggs of the Silk-worm, I procured a number of those eggs, which had been lately laid by the Moth or Butterfly produced from that insect; this was about the beginning of the month of September. These eggs, when first laid, were of a yellowish colour, which in about two days time assumed a reddish cast, and at six days end they appeared to the naked eye of a liver colour. Several of them I opened, by taking off the upper part of the shell with as light a touch as possible, and in every one of them I observed an exceeding small and delicate membrane, which to the naked eye appeared blackish, but on examining it by the microscope, I found the real colour to be violet, but where the violet particles composing it lay close together, they assumed a blackish appearance. This membrane lay next to the shell of the egg, and I imagined, that within it the future Silk-worm would be formed; and in the part where this membrane was joined to the shell, I saw a minute speck or spot, which I concluded to be the vital principle, and the rather, as this speck was wanting in those eggs which I found to be afterwards barren; and it is further to be noted, that in the barren eggs no such membrane as I have mentioned was formed, nor did they change their original yellow colour. This membrane in a short time extended over the whole inside of the egg, and being seen through the shell, which is transparent, caused it to appear of a bluish colour.

Some of these eggs, which were six weeks old, I put into a flat

screwed box, which in the day-time I carried in my pocket, and at night placed beside me in bed, that they might continually be kept warm; and in another box of the same kind, I put some more eggs, three weeks old, and these my wife (who was always very warmly clad) constantly carried in her bosom. This we did, to try the experiment, whether it were possible to promote the growth of Silk-worms in the autumn.

In the month of October I opened some of the eggs which I had thus kept by me for about a month, and in one of them, I observed a minute Silk-worm, about the thickness of an hair, and proportionable in length, but I was not able to distinguish any particular parts in its body. In the space of ten days more, I found larger worms in the eggs, whereupon, I opened some of those which my wife had carried about her, and in those, I saw Silk-worms, which by the microscope, appeared as large as one's finger, and these I proposed to have given drawings of, but the animals soon drying, and all the moisture in the eggs evaporating, they entirely lost their figure, so that neither the head nor tail, nor any other parts of their bodies could be distinguished, although I had very plainly seen them when the eggs were first opened.

After this, I from time to time opened others of these eggs, but I could not perceive any farther growth in the animals, and at length all the moisture in the eggs so dried away, that they lost their shape and became flattened.

In the beginning of May, in the following year, I opened several of the eggs which had remained all the winter in my study, and then I observed minute Silk-worms within them, and a kind of globular particles lying close to them, which I judged would afterwards be formed into the limbs of the animals.

Towards the end of this month, the Silk-worms increased in growth very rapidly, so that on the 20th of May, upon opening several of the eggs, I could perceive, not only several parts of each

animal's head, but also a great number of small vessels in it which branched out into others extending all over the body, particularly to those parts where I could perceive the claws begin to appear, and which, therefore, I concluded, were nourished by those vessels. In short, I saw such multitudes of vessels, with their branches, all of a blackish colour, as is not to be conceived, for when these branches became beyond measure slender, they lost their dark tinge, and at length became invisible. And I can safely say, that I do not think I have seen so many arteries pictured in the drawing of an human body, as appeared in these objects, which I should have given a drawing of, but the moisture in these minute vessels dried so quickly, that they lost their figure, and could no longer be distinguished.

On the 21st of May, I opened several more eggs, and saw that many of the Silk-worms in the space of the last twenty-four hours were so much grown, that they appeared compleatly formed, for I could not only see the head perfectly formed with all its parts, but also all the claws and limbs, and the body every where covered with hairs: upon opening these Silk-worms, I saw the intestines, and now the membrane, which hitherto had inclosed the animal, was disappeared, the substance thereof by this time having passed into its body, which had assumed a blackish colour, but the head was particularly black, and I perceived some motion in the animal when taken out of the egg.

The next morning, upon opening more eggs, each Silk-worm which had lain in a round posture within, immediately extended itself and crept about, and I found that all the moisture which I had hitherto observed in the eggs was gone, it having passed into the body of the worm, which was perfectly dry. In the afternoon of the same day, I observed that several worms had crept out of the eggs placed in my closet, whereupon I sat about examining the remainder of those eggs, chusing such of them, wherein the formation of the ani-

mal appeared to be least advanced, whereas before this I had opened the most perfect ones : and these I found in the same forwardness of growth as the eggs I had opened on the 20th of May, and by this time all the dark coloured bodies of the animals, especially the head, might plainly be discerned through the transparent shell.

This rapid formation of the Silk-worm, and its motion within the egg, excited in me the greatest admiration, and if I had not prosecuted the observations I have been relating, I should have thought it absolutely impossible : for, in the preceding autumn, I had placed these eggs in a much greater degree of heat than they were now exposed to, and yet I could not at that time promote the perfect formation of the animals within them. And, from my present observations, I was led to conclude that it has been an essential property of this creature, implanted in its species at the first creation, that the vital principle must lie shut up in the egg for more than the space of six months, without any augmentation of its substance, except in the formation of that part which is to serve first for the defence and preservation, and afterwards for the nourishment and increase of the animal, and this is the membrane or skin I have before described ; and that were it not for this provision made by nature, the whole species of the Silk-worm would be liable to perish in one year : for if a warm season in autumn should cause the worms to be excluded from the eggs, the succeeding cold and rains must prove their destruction.

I observed that the Silk-worms always came forth from their eggs in the morning, and not in the afternoon. To ascertain this, on the last day of May, in the evening, I counted the eggs I had then left, which I found to be about two hundred. The next day, namely, on the first of June, at six in the morning, ninety-seven Silk-worms had come out of their eggs, and the same day at dinner-time, or about one o'clock, thirty-two more. In all the afternoon, although the atmosphere was warm, only one made its appearance ; but the next

day, at seven in the morning, forty more were excluded from their eggs.

I always found, that the opening in the shells, through which the worms crept forth, was blackish about the edges, and, as I could not conceive this blackness to be caused merely by the touch of their bodies as they crept through the opening, I carefully observed the animals at the time they were employed in biting or gnawing open the egg, and I always perceived, that in doing this, they frequently emitted a blackish watery humour or liquid from their mouths, with which they moistened the shell in that part where they were biting it, and this not merely on the inside, for when they had made the aperture large enough for them to emit this liquor on the outside, they then moistened the shell both within and without. I also observed, that when the worm was about moistening the shell, it ceased biting or gnawing for a short time, until (as I suppose) it had brought into its mouth a portion of the liquid for that purpose, in like manner as oxen, while chewing the cud, desist at intervals for a short space, until they have produced a fresh portion of their food from their stomachs.

From hence I concluded that without this kind of liquid, it would be impossible for the young Silk-worm to open to itself a passage through the shell of the egg. And I saw that the animal was very sparing in the consumption of this liquid; for in that part where it had moistened the shell, it continued to bite or gnaw (without moving to a fresh place), until (as it appeared to me) it had eaten or taken into its mouth the liquid, and the bitten or scraped-off part of the shell. At which inconceivable perfection in this little creature, I was struck with astonishment, and I drew from it this conclusion in my mind, that not only the Silk-worm, but other creeping insects, when come to maturity in their eggs, do emit some liquid matter from their bodies, in order to soften the shell in that part where they are endeavouring to break forth, and possibly this liquor may have in

it some acute or corrosive salt, fitted for softening the shell of the egg.

I cannot quit this part of the subject, without exhibiting the formation of the Silk-worm's egg, because the several particles of which it consists, are so firmly and closely united together, that they preserve the liquid substance within the egg many months without the least evaporation.

Plate II. *fig.* 25, FGH, is the shell of the Silk-worm's egg, opened by the animal, as it appeared to the limner through the microscope; GH, is part of the aperture which the worm, by biting or gnawing, opened for itself, and through which it crept out of the shell.

Some years after the preceding observations, I further prosecuted my enquiries by observing the Silk-worms as they advanced in growth, which I could easily do, having two mulberry trees in my garden, which supplied me with food for the worms, of which I had three or four hundred.

I have often by the microscope examined the cuticle or thin skin which is shed by these insects the * last time before they are full grown, and particularly the more solid part of it which covers the head; and with great wonder, I beheld in it all the organs or members with which the head is furnished, and particularly I saw a number of eyes disposed on each side of the head, in fit order to enable the animal to see every object around it: further to examine which, I have several times cut off the heads of full grown Silk-worms, for otherwise they were in such continual motion, that I could not clearly distinguish these eyes. When the Silk-worms were changed into aurelias, I saw the skins of their heads and the rest of their bodies, which they had put off on the change, and upon examining these by the microscope, I always found the horny coats of the eyes in their cast-off skins. Several parts or pieces of the head with the eyes in

* Silk-worms shed their skins four several times, before they begin to spin their cone or covering.

them, I placed before the microscope, and delivered them to the limner, that he might make a drawing of one of them.

Fig. 26, Q R S T V W, represents one side of the Silk-worm's head, with six eyes placed therein; on view of which, it plainly appears that the eye marked with the letter Q, is designed to view objects directly in front; that marked R, to look a little obliquely forwards, and at the same time upwards; the eye marked S, to look on one side, and at the same time a little upwards; that marked T, to look rather backwards, and also obliquely upwards; the eye marked V, to look entirely backwards; and that marked W, downwards. And, considering that the eyes of these creatures are immoveable, the number and position of them as before described (six on each side), are the best calculated for enabling the animal to see all circumjacent objects.

At the same time, I observed the teeth or pincers with which the head is provided, and with which this animal bites or chews the leaves it feeds on; a row or set of these teeth is placed on each side of the head, and they most exactly fit into or correspond with each other. *Fig. 27, A B C D E*, represents those teeth which were placed on the right side of the head, and here may plainly be seen how each tooth has a thickness or rising about the middle of it, in order to give it strength, whereas the parts of the teeth between D E, are exceedingly sharp and fine, in order more effectually to cut or chew the leaves: and each of these teeth has the same thickness or rising, both on the inside and outside. The part represented at A B C D, appears very thick in proportion to its size, but upon more narrowly examining it, I found that this thickness did not consist of a solid bone, but was hollow within, which cavity probably had been filled by some kind of muscle. At A and B, appear two round bony parts, which in my opinion fit into hollow sockets in the head, so as to give the teeth free and sufficient motion.

When I first examined the Silk-worm's thread by the microscope, it seemed to me not to be of a round form but flat, for the same thread appeared in some places four times thicker or broader than in others ; I also thought, that each of the threads was double, or composed of two others, forasmuch as the middle of the thread always seemed darker than the rest, and the whole appeared, as if one were to suppose, two transparent threads lying close and parallel to each other, and glued or fastened together, and each of these two threads not to be so pellucid at the sides as in the middle.

I next considered with myself, whether these single threads might not be composed of many smaller ones, and having at length found means to break or separate them into very small fragments, I plainly perceived each of them to be composed of a number of excessively minute filaments.

Farther, I placed a Silk-worm which was beginning to spin its ball or covering, in a glass tube, large enough to give the animal liberty to move and turn itself about, and I observed it to fix the thread in various places, sometimes to the glass and afterwards to the threads already spun, by means of a certain glutinous or gummy matter, with which the threads are smeared when they first issue from the animal's body. In the progress of its spinning or forming its ball or cone, the Silk-worm frequently changed its position, and carried the thread by various turnings and windings in every direction, it being implanted in this creature by nature, always to form its cone or web of an equal substance and strength in every part next its body.

Upon examining this cone or ball of filk by the microscope, I perceived in hundreds of places, that the threads of which it was composed, were not single but double threads, and this was more particularly distinguishable in those places where they were bent in a very short elbow or turning in their fixure, either to the glass or to one another. This is explained at *fig. 28, A B C D*, which represents

a very small particle of the Silk-worm's thread, and this is here seen to be formed of two others, which, for the greatest part, are joined together as at letter A, but where there is a short turning or winding they are separated, and appear in two parts. This double thread remains united, by means of the viscous or gummy matter before mentioned, until, by being immersed in water, the gum is dissolved.

Now, if we consider that the Silk-worm's threads are not round but flat, we shall presently discover the reason why no substance, whether of wool or hemp, how fine soever it may be, can be formed into cloths or stuffs, that will compare with filken garments in the glossiness of their appearance. For, the flat surfaces of the filken threads, reflect the light more copiously and strongly, producing their glittering or glossy appearance, whereas the light which shines on small round bodies is very little reflected from them.

In order to exhibit the flatness of these double threads more plainly to the limner, I twisted some of them a little, and then placing them before the microscope, I caused him to make a drawing thereof. One of these threads is shewn at *fig. 29*, EFGHI, and between the letters FG and HI, it is pictured as seen obliquely, proving that the threads as spun by the worm are not round but flat; they are likewise so transparent, that one thread can easily be seen through another which is placed upon or over it.

Let us but attentively consider the make and composition of such a thread as the Silk-worm's, bearing in mind also, how wonderful must be the structure of the creature's body from which these double threads are produced, each of which again consists of a great number of oblong particles or smaller filaments; and when we further reflect that from so moist and watery a body as is the Silk-worm's, such strong and tough threads are produced, capable of being applied to the many purposes we continually experience, who, upon seeing all

this, can refrain from exclaiming with me "How inscrutable and incomprehensible are the hidden works of Nature!"

The silken case or web of which I am now treating, and which the industry and ingenuity of mankind has converted to so many useful purposes, is constructed by the animal for no other end than that, when its change into a chrysalis or aurelia approaches, and it cannot then be concealed under the leaves of the trees, nor can during the time of its change adhere to any thing, nor even change its place, and during all that time lies as it were motionless, it may be preserved from becoming a prey to birds; and this I am well convinced is the case with all insects of the caterpillar kind, which, when they are full grown, and their change approaches, wrap themselves in some kind of web or covering.

But my chief object, in all these my observations, was, to discover as much as possible the nature of that organ from which these two threads proceed, and by what contrivance they are joined so closely together: the common opinion respecting which threads is, that they issue from the animal's mouth. For this purpose I found it necessary to fix a Silk-worm on its back, and then the organ, which is placed below the mouth, appeared in sight. *Fig. 30, A B C*, exhibits this organ. The parts marked *D E* and *F G* are placed below the mouth, and the organ from which the threads issue is situated still lower. While the limner was making this drawing, some part of the teeth appeared in his view, which he also included in the figure, at the letters *H I K*, and this was done, more clearly to prove, that the threads do not proceed out of the Silk-worm's mouth, as is the vulgar opinion.

After I had discovered the particulars above enumerated, I endeavoured to investigate the matter or substance from which the threads are formed in the body of this insect. For this purpose I cut off the heads of several Silk-worms which had begun to spin their web or cone, and then I saw, besides the other internal parts, two oblong

and round bodies four times folded or doubled together, which I took out of the animal's body. These parts were almost twice the length of the Silk-worm, and at one end, the situation of which I conceived was in the head, they terminated in a point, and sometimes I saw issue from this pointed end, an excessively slender thread, four times the length of the Silk-worm.

These organs, or rather vessels, in the thickest parts of them, were of a red colour, yet when examined by the microscope they seemed yellow; but when I separated the inner from the external part of them, the exterior part seen by the naked eye appeared of a perfect yellow.

Fig. 31, LMN, shews one of these bodies or parts which I have been just describing, and of the same size it appeared to the naked eye when dry and contracted. The letters M and N denote how far the red colour extended; from L to M was of a perfect yellow, and here I judged that the thread when produced from the interior part of the animal's body was kept ready for use. At N is the small end, the situation of which was near the head, and indeed within the head itself. Between L and O, in my judgment, is the way or passage through which is conveyed the matter or substance of which the threads are composed. This part was of a yellow colour, and is longer than here pictured, being broken off at O. Another part or organ of the same make and shape, was also contained in the Silk-worm's body, and from these two parts the substance is supplied for producing the two distinct threads I have been describing.

Sometimes when this part or organ was broken off at N, I perceived in it a kind of cavity, but extremely minute.

I oftentimes took hold of the end of the thread which the Silk-worm was preparing to spin, and drew it out from the body with so much rapidity, as by twenty-five times to exceed the swiftest motion of the worm in its own spinning; and I found that when the thread was drawn forth to the length of about fifteen or sixteen inches, it broke

off, either near the organ from whence the threads proceed, (marked in *fig. 30*, with the letter C) or else within the body of the Silk-worm itself. And on these occasions I also observed that the threads were covered with much more of the viscous or gummy substance than usually adheres to them when spun by the worm, which substance also appeared of a yellow colour.

Further, I took a Silk-worm which had spun more of its ball or cone than any I had before examined, and on opening it, I perceived that the part which in *fig. 30*, had appeared of a red colour was now quite yellow; and when I opened another Silk-worm which had, as it were, consumed or exhausted all its filk in spinning the web, the same parts appeared quite of a pale colour.

When I examined by the microscope that part which is represented in *fig. 31*, at LMN, I discovered in it a great number of blood vessels, mostly composed of annular parts or rings. A small portion of one of these vessels in a place where it divides into two branches, is represented at *fig. 32*, FGH IK. This was not one of the largest vessels I saw, for near to it was one four times the size.

I have at several times when the Silk-worms had, as I supposed, nearly finished their web or covering, cut it open, in order to observe the change they underwent, and at that time I remarked, that when the skin about the head became loosened, the worm was then changed into a chrysalis or aurelia, and nothing wanting to complete that change, but the putting off its skin of a worm. But when I myself endeavoured to strip off this skin, I found the under one so soft and tender, that I could not avoid injuring it.

Moreover, I have examined by the microscope the Silk-worm, when it first issued from the egg, to discover, if possible, whether the exceeding slender thread spun by so minute a creature was a double thread, and in more than one instance, I found this to be the case. These threads I judged to be above a thousand times slenderer than those spun by full grown Silk-worms, and they were all covered

with a proportionable quantity of the glutinous or gummy matter before-mentioned. In short, there is no doubt that the same perfections exist in a newly-hatched Silk-worm, as can be discovered in one full grown.

I have frequently examined the flying insect, moth or butterfly produced from the aurelia or chrysalis of the Silk-worm; and, having before particularly described the eyes of this creature while a worm, I now employed myself to discover the nature of its eyes, when changed into a moth; and for this purpose I placed before the microscope one of those organs of sight, which in this animal is commonly deemed one eye. This is protuberant or rising above the head, rather more than an hemisphere, and is composed of a number of smaller optical organs: These I counted with the greatest exactness I was able, beginning at the bottom of the hemisphere, and proceeding to the summit or uppermost part of it, which distance made the fourth part of a sphere; and in this space I counted thirty-six optical organs or eyes. But, not satisfied with my own computation, I delivered the microscope to the limner, desiring him to count them, and in the same space he reckoned thirty-five. This latter number I will suppose to be right, and from it I proceed to compute as follows:—If the fourth part of the circumference or great circle furrounding a sphere contains thirty-five, the entire circumference will contain 140. Now Metius informs us, that having the length of the great circle in a sphere, the calculation of the whole superficies of such sphere is best and easiest computed, thus: As 22 is to 7, so is the quadrature of the great circle to the superficies of the sphere, therefore in the present case the computation is as follows;—

As 22 ——— 7 ——— 19600

$$\begin{array}{r} 7 \\ \hline 22 \overline{) 137,200} (6236 \\ \hline 8 \end{array}$$

140 the circumference or length of the great
140 [circle.

$$\begin{array}{r} 5600 \\ 140 \hline \end{array}$$

19600 the quadrature of the great circle.

From hence it follows, that each of the small parts or organs of sight of this insect, which is vulgarly deemed but one single eye, is composed of more than three thousand optical organs or eyes, but if both parts together constitute a sphere, they then contain 6236 optical organs or eyes.

I have caused this part or eye of the insect to be drawn of the same size as it appeared to the naked eye of the limner, to give the better idea of the wonders which are concealed in so small an animal. This is shewn at *fig. 33*, between the letters L and M. Each of the optical organs contained in this eye is separated from the rest by a line or division of six sides, or of an hexagonal figure, and all these hexagonal organs or eyes are placed in the most exact order that can possible be conceived. A few of them, as seen by the microscope, are seen at *fig. 33, a, b, c, d*.

When this little part, cleared from the optic nerves within it, was place before the microscope, all the surrounding objects were clearly to be seen through each of the small optical organs I have been describing, though wonderfully diminutive; for the great tower or steeple of our new church in Delft, which is three hundred feet high, and about seven hundred and fifty feet distant from my house, when viewed through any one of these optical organs, appeared no larger than the point of a small needle seen by the naked eye: and from hence may easily be collected how minute the optic nerves must appear to me.

Now, if we consider that a Silk-worm, within the space of eight or nine days, shall not only have spun its web, cone, or ball, but also shall be changed into an aurelia or chrysalis, and that in the same space of time, not only its eyes but all the members pertaining to it as a flying insect shall be formed, who can avoid being struck with amazement at all these wonders in one Silk-worm? And yet, how little do we discover in comparison of those things which now are and for ever will be hidden from our sight? the whole of which I

am fully persuaded no one will ever be able to dive into, and to explain their causes and effects.

If we examine the wings of this creature by the microscope, we shall find them covered with an incredible number of feathers, of such various forms, that if an hundred or more of them were to be seen lying together, each would appear of a different shape. To shew more clearly this wonderful object, I caused eight different feathers to be delineated, for I do not remember that I ever saw them of so curious a make in any other flying insect. These feathers are shewn at *fig 34*, ABCDEFGHIKLMNO, and the letters ACEG ILN, denote their quills which were fixed in the membrane or skin of the wing.

Although the microscope by which these feathers were drawn, represented objects very distinctly, the limner could not, through it, see the streaks or ribs in each feather, until I pointed them out to him. Therefore I put into his hands a microscope which magnified objects almost as much as that by which the Silk-worm's thread was drawn, desiring him to give the figure of that feather which through it he could see the most distinctly. This is done at *fig. 35*, PQR, in which plainly appear a great number of streaks or parts like ribs, which give strength to the feather, and in some of these feathers, where they spread very wide, as at the part marked R, I have counted as many as thirty of these streaks, and if we consider that every feather is nourished through the quill which is pictured at P, how many and how various must be the vessels in this quill?

After this, I wiped off the feathers from a part of one of the wings, that I might discover how close they were placed together, and I found that they were about an hair's breadth asunder. And if, as a certain writer asserts, 640 hairs breadths are equal to one inch, we may demonstratively conclude, that the four wings of this insect are covered with more than four hundred thousand feathers, for the sur-

face of all the wings when laid side by side takes up almost three quarters of a square inch ; and, as each wing is covered on both sides with feathers, this makes the space of an inch and an half square. To which if we add, that the body and legs of this butterfly are covered with as many feathers as are on the wings, the number of feathers above enumerated will be doubled.

I then examined the boney parts which give strength and stiffness to these wings, and I saw more plainly that in other flying insects the crooked or twisted veins within them. A very small portion of one of these boney parts is shewn at *fig. 36*, ABCDEF, within which is seen that twisted vein, and where the bone is divided into two parts, the vein is the same. In the same figure, at ABH, is represented a small part of the membrane or skin of the wing stripped of its feathers. The dots in it indicate the cavities wherein the quills of the feathers had been fixed.

It is also a pleasant object to behold the curiously formed claws in each of the short feet of the Silk-worm, and which are shed or put off with the skin at the animal's change into an aurelia, one of these is shewn at *fig. 37*, I K L, and when changed into a flying insect or butterfly each foot is furnished with two nails or claws, with which it very strongly clings to every thing it touches. These nails or claws are shewn at *fig. 38*, M N O.

To close this subject ; seeing that the Silk-worm, in its change, only puts off the skins of its feet, and that, in the same places where, while a worm, it had very short feet ; it is, when a butterfly, furnished with legs, covered with numbers of feathers, and armed with nails or claws as before described, the metamorphosis or change of this creature must seem almost incredible, and cannot but excite in us the greatest admiration.



(66)

On the nature of the scales of Fishes, and how the age of those Animals may be determined by observation of the scales; The Author's reasonings and opinion respecting the Longevity of this part of the Animal Creation.

IT is the opinion of the Jews that they are forbidden by their law to use the Eel as food, because that Fish is said to be without scales; and in the book of *Deuteronomy*, Chap. xiv. v. 10. it is written, "whatsoever hath not fins and scales, ye may not eat, it is unclean unto you;" and in *Leviticus*, xi. v. 12, are these words, (which they apply to the same species of Fish,) "whatsoever hath no fins nor scales in the waters, that shall be an abomination unto you.

But when I examined this kind of Fish, by the microscope, after I had cleared away that viscous or slimy matter which adheres to them, I found their skins to be as completely covered with scales as those of any other river Fish, which scales (though very small and thin) lie as close together and are placed one on another in as regular order as can be observed in any other Fish whatever, whether of fresh or salt water. Moreover, this species of Fish is provided with fins equally as others, namely, one at the head, and one above, and another below, the tail; and because I apprehend that this discovery of mine is new, at least to persons of the Jewish nation, (for to this day they deem this delicate Fish to be unclean, and hold it as an abomination to them,) I determined to give a figure of one of these

scales, (taken from the belly of the Fish, where they are the smallest,) as it appeared through the microscope.

Plate III. *fig.* 1, A B C D, exhibits this scale; it was taken from the belly of a large Eel, which, next the head was of the thickness of seven fingers or thereabouts: on the back and sides of this Fish the scales are larger. The greatest part of this scale, A D C was covered by two others. The part B, was placed towards the tail, and in this position were all the scales; they were all principally composed of a kind of globules or little balls, which globules in many places exhibited an appearance, as if they were covered with a cobweb, which by reason of its excessive fineness, could not be expressed in the drawing.* In these scales the globules composing them were very transparent, though some more than others; again, some had in them a dark spot. These opaque globules lying in rows contiguous to each other, produced the appearance of divers circles or rings on the face of the scale. And although I did not observe these scales to be exactly alike, yet the circles or rings seemed to me to be of the same number in all of them, whence I was led to conclude, that the scale had been every year augmented by the addition of one circle, and consequently, that, as there were seven circles in this scale, this Eel was probably seven years old. These circles are marked in *fig.* 1, by the letters E F G H I K L, and at X the scale is represented of the same size as it appeared to the naked eye.

Having examined the scales on the body of a very large Eel, I perceived that those on the back and belly of the Fish were placed in regular and even courses behind each other, but that those between the back and the belly were many of them laid obliquely, some towards the belly and others towards the back, but all so disposed as to cover the skin exactly in every part.

* This appearance seems to have been afterwards more fully investigated by the Author, and explained by a drawing, as will appear in the following pages.

* After this, I examined the matter or substance with which these scales are covered, which, as well as the scales, has been generally deemed nothing more than slime, and is by most persons thought to be an excrementitious matter, adhering to this species of Fish; but I am now convinced by experience, and the clearest ocular demonstration, that this supposed slime does not collect on the animal's body from without, but is really part of the body itself; forasmuch as this substance, although it appears to the naked eye, and very often through the microscope no otherwise than like a crystalline or pellucid humour or substance, yet in fact it is no other than a congeries or collection of veins or vessels, which in their exquisite fineness or slenderness do almost exceed belief, spreading themselves one among another in such an incomprehensible and immense number of branches, that I could not contemplate them without the greatest admiration. Indeed, many were so thin and slender, that I could not discover them without the most careful attention, and I thought it probable that there might be others still more minute, so as entirely to escape the sight. Such of these vessels as I could distinctly perceive, I judged to be so small (measuring them by my eye) that if one of the globules† of blood from whence its redness proceeds, were to be divided into a thousand parts, not one of those parts could pass through these wonderfully thin and slender vessels.

From these observations I concluded, that this substance only answers the purpose of a membrane or skin lying next to the scales, and that, when an Eel is creeping through a narrow passage or hole,

* These observations of the Author on the Eel appear to have been written posterior to the time when he published the preceding ones, and it should seem, that what he before describes to be an appearance like a cobweb adhering to the scales, is the effect of the vessels here described.

† The author's computation of the size of a globule of blood, will be found in another place, where he treats of that subject.

a part of this membrane or cuticle, which we call slime, is rubbed off in the passage; and that when Eels are kept in any kind of vessel without water, and in their motion wear off this cuticle, they cannot long survive; and upon my talking over this subject with a Fish-monger, who was a very intelligent man in his business, he confirmed all that I have here mentioned.

Further, I imagined that this cuticle or skin so covering the scales of Eels, and in some sort proceeding from the scales themselves, and the vessels which in a great measure compose that skin which we imagine to be slime, extend so far and wide, that the vessels proceeding from one scale spread over more than twenty-five others, and that this is the reason why this slimy matter covering the scales is so thick and tough.

But, not yet satisfied with these observations, I endeavoured to find out the vessels in the scales from whence these slimy excrementitious vessels were formed, and in order to exhibit more plainly the rough or wrinkled make of the scales, I have caused an exceeding small particle of one to be delineated, the appearance of which, by the microscope, was that of a lucid or bright crystal, both within and without. This is shewn in *fig. 2*, I K L M, wherein the side I M, represents that part which was fixed or rooted in the Fish, being about the length of two common grains of sand. I have sometimes divided the scales of this Fish into small parts, and I always found that though the wrinkles in them appeared very pellucid, they were composed of nothing but those inconceivably slender streaks, or rather vessels, mixed and twisted one within another, as is in some sort represented in this figure by the letters K L N.

Some years after the preceding observations were published, I received from a person of some note in this city, a parcel of scales taken from a very large Carp which had been kept in his Fish-pond, and was so tame that it would take food out of a person's hand.

But in the time of a severe frost, the gardener being employed in breaking the ice with an hatchet, to give fresh air to the Fish in the pond, this Carp came to the hole, and unfortunately received a wound from the hatchet, which occasioned its death. This Fish was in length $42\frac{1}{4}$ inches, and in circumference at the thickest part of its body $33\frac{1}{4}$ inches.

In order more easily to cut one of these scales in pieces, I steeped it in warm water, and then I cut off a slice from it, passing through that part where the first formation of the scale appeared, which original scale was very minute, and I then observed forty rows of scales lying one on another, or in other words, this single scale was a cluster of forty other scales lying one on another. For every year a new scale somewhat larger than that immediately preceding it, is added to the number, and is as it were glued to the former ones; therefore as many of these scales as are found thus joined together, so many are the years of the Fish's age. This assertion of mine is however violently contradicted, because many people think that I cannot by any means prove what I affirm.

I determined therefore, to cut off a slice from this scale very obliquely, whereby the rows of the component scales might be more clearly discerned, and I caused a drawing of this to be made from the microscope, which is shewn at *fig. 3*, A B C D; the part reaching from A to B, or from D to C denotes the difference in size by which each newly-formed scale exceeds that of the preceding year, the whole thickness of the scale as it appeared through the microscope, is the space between B and C, but in fact, the real thickness, as seen by the naked eye, is no more than that of an hog's bristle.

Another piece of the same scale, cut still more obliquely, I placed before another microscope, a drawing of which is given at *fig. 4*, E F G H. The space between E and F is the thickness of the scale, and as many divisions or rows as are there pictured, so many of the

small component scales lie heaped one on another, (at least as far as the limner was able to observe them) and so many years had elapsed between the formation of the first scale, and all the others which were added to it.

This cutting or slicing off pieces from the scales, does not succeed equally well in all, for sometimes their thinness causes it to fail, but if the extremity of each scale can but be perceived, the age of the Fish may be gathered from it with little danger of mistake. In order to shew this irregular kind of section, I caused a small piece of that description to be drawn from the microscope, and this is shewn in *fig. 5*, I K L M; here the additional scales produced every year, sometimes appear of a darker shade than they are in reality, and therefore the yearly increase in size seems represented at I O and M O, but the addition of three years' growth appears at I O K. At *fig. 6*, between P and Q, is shewn the natural size of the slice or piece of scale represented when magnified, at *fig. 4*.

Since we now find, that the scales of Fishes are every year augmented in the way I have been describing, we may form a pretty good judgment as to the time when this augmentation is made by analogy to what we observe in the other productions of nature, and thence we shall conclude that the additional scales are compleated at that season, when the further growth ceases. For this is evident in trees, at least such as grow in these regions. The like also is the case in regard to cows, for between certain spaces of time, when their growth is intermitted or ceases and when it again returns, it is shewn in the horns, whence we gather that as many knots or rings as are found on the cow's horn, so many years of age is the animal.

And, though this may not appear exactly in the same manner in all creatures, yet we must allow, that such a distinguishing circumstance exists, and this is proved in the falling off of the hair from animals, and the shedding of feathers by birds, at certain regular periods.

I have often considered with myself, respecting the longevity of Fishes, and I am persuaded that in deep and extensive waters, and in running streams, where the water does not corrupt or putrefy, they are not liable to any diseases, nor ever die of old age. Such wounds as a Fish may receive, either by swallowing the hook baited to catch it, and which, being broken off and remaining in the stomach, may cause an exulceration; or by devouring some substance which it cannot digest, are not to be deemed diseases, but accidents. Now, terrestrial animals, through great fatigue, heat, cold, hunger or thirst, may easily fall into distempers and die, but to those accidents Fishes are seldom or never subject.

First, as to fatigue, this in Fishes cannot be great, because their chief exercise consists in the larger pursuing the smaller, in quest of them for food; or in the flight of the smaller ones from the larger; and in these exertions the fine juices of their blood can in no degree, or at least but very little, be exhausted; because in such kind of pursuit or flight, no evaporation can be produced from their bodies through heat or dryness; besides, they never want for drink, by which means their blood, and the other juices of their bodies are kept continually diluted, so that the circulation is constantly preserved.

No one can pretend to say that a Fish is ever killed by heat, for many kinds of fish, in the middle of summer, and in the burning heat of the sun, do either play, as it were, on the surface of the water; or hide themselves under the leaves, weeds, or other substances at the bottom.

As to cold, we do not know that Fish in deep waters ever perish with cold; but we know by experience, that at such seasons they seek the bottom of the water.

As to food, they are not easily killed by hunger; many Fishes live for five or six months space without any other support than what they

receive from the water, or rather from the small particles in it, which are by us commonly considered as part of the water only ; in such a situation indeed, they increase little or nothing in size, but rather, if they were before fat and plump, they will fall away.

I am also persuaded, that all Fishes which have a constant supply of food, do daily increase in size, and this without ever ceasing to grow, so that any real definite size cannot be assigned to them, as it can to terrestrial animals, some of which arrive sooner, and others later, to their full and perfect stature, which they never afterwards exceed, although they continue to live many years. The reason of which, I am convinced is this, that terrestrial animals continue growing as long as their nutritive juices have force sufficient to protrude or thrust themselves through the cavities of the bones, and so to increase the size of them, as well in length as in thickness. But when the bones of these animals, by being exposed to the air, are become so rigid and hard, that they cannot be any more distended, their farther growth must necessarily cease, and any fresh supplies of nutritive juices can only tend to increase the animal's fatness. But the bones of Fishes are for the most part destitute of marrow, and they cannot be rendered rigid by exposure to the air, consequently the very small tubuli or pipes of which they are composed, are exceedingly soft in comparison with those of other animals. All which considered, there seems no reason to exist, why the bones of Fishes should not continue always growing, so long as the animals do not want for food.

In the lakes with us, where are many Fisheries, Pike have been caught of the length of 56 inches, and 36 or 38 pounds weight. Perch also 28 inches long ; and who can tell to what size these Fishes might have arrived, if they could have longer escaped the nets ?



The Author's refutation of the doctrine of equivocal or spontaneous generation in the instance of the Sea-Muscle, with a particular description of that species of Fish.

I HAVE been informed, that a book is published at Rome, by a learned Jesuit, named Philipppo Bonanni, wherein he maintains, that animalcules, or small living creatures, can be produced out of inanimate substances, such as mud or sand, by spontaneous generation, according to the doctrine of Aristotle; and it seems that this learned gentleman is himself very desirous to see my observations on the subject. I shall therefore proceed to consider Signor Bonanni's positions, and I doubt not, that upon investigation, they will be found of no weight or substance, but will vanish like smoke or vapour.

We will admit, that out of the mud or sand which is found on the sea-shore, or the beds of our rivers, at low water, shell-fish or testaceous animals come forth; but it does not from thence by any means follow, that they are produced without any regular course of generation.

Among the mud, in the creeks or shallows of our sea coasts, are taken great quantities of that shell-fish, called Muscles, which are used by us as an article of food; and, as I had in the autumn been employing myself in observations upon this species of fish, I applied to a fisherman who made it his business to catch Muscles, and questioned him as to what his opinion was, with regard to the propagation of that fish.

This fisherman, who was a very intelligent man, and of good estimation in his profession, and had been brought up to it from his youth, informed me, that he had often experienced, that in the same tract of coast where he had found for several years successively very good Muscles, and in great abundance, yet afterwards in or about the same place, very few or none were to be got ; for which he assigned these reasons :

“ At the time of the Muscles laying their eggs or spawn, which lasts but for a short season, this spawn, by strong tides and heavy gales of wind, will be carried from the places where it is deposited, and when the water becomes still and calm, it will sink to the bottom, or adhere to the weeds growing there ; and then in the space of two or three years, a good and plenteous Muscle-bank will be formed in the place ; adding, that by this means Muscles are taken where none were ever found before, and Muscle-banks formed of very great extent, the spawn laid by the Muscles being in such abundance, as to make the sea-water appear of a white colour.”

If then, at the season when the Muscles deposit their eggs or spawn, we take up a quantity of the mud or sandy matter from the shore, and keep it covered with water, we need not wonder if we find Muscles or other shell-fish produced from thence ; but if we imagine that this comes to pass by any other means than the ordinary course of generation, we shall therein deceive ourselves. And for my part, I hold it equally impossible for a small shell-fish to be produced without generation, as for a whale to have its origin from the mud.

The eggs or spawn of Muscles, and other shell-fish, being carried along with the sea-water to the sides of ships lying in harbours, will adhere to them, and become shell-fish, by which means those ships in their voyages to other countries, will introduce such kinds of shell-fish as were before unknown in those parts.

But how can it be conceived that living creatures can proceed from

sand, or obtain any nourishment from thence ? for there is no other difference between the grains of sand, and the beach-stones on the sea-shore, than that the one are larger than the others ; and, as incapable as glass is of affording support to any living creature, so is it impossible for any nourishment to be found in sand.

If it were possible for the mere sand on the shore to produce shell-fish, how much would our coasts abound with them, and not with them only, but also with all other sorts of fish ; for the flat-fish feed on these small shell-fish, and thereby become very fat and good ; and so does also the whiting.

The chief reason, in my opinion, why we do not find shell-fish in equal plenty, at all times, is, that the strong north-west winds blowing directly on our coast, do so stir up the sand and muddy bottom on the shore, that the shell-fish are thereby overwhelmed and buried, and so perish.

During the last five or six years, we have not had any great storms from that quarter, and we have for these last three or four years successively, had such excellent flat-fish, especially flounders, that no one remembers to have seen the like ; the reason for which I have already assigned, namely, that the shell-fish during that space of time, multiplied exceedingly, affording plenty of food for fattening the flat-fishes. And this is also proved by experience ; for whenever flounders are in perfection, their stomachs and bowels are found to be full of fragments of small shells. And, upon reflecting with myself as to the cause of these small shells being so broken into fragments, I could not assign any other reason than the following :

The flounder, sole, turbot, and other flat-fish, are formed by nature with their mouths distorted and in a different position from that of most other fishes ; and this formation seems to be, for enabling them to pick up their food from the bottom of the sea, and not to go

in chase of other fish ; and I conceive that these flat-fish, when picking up the small shell-fish, do break their shells to pieces in their mouths (which seem to me to be formed principally for that purpose) and then swallow them, rejecting those shells which are too hard for them to break, for which reason we never find any very hard or large pieces of shells in their stomachs ; and it is not in the power of the flat fish to separate these smaller ones from their shells, because they are all, as far as I have ever observed, closely united to them by ligaments or tendons, and always keep their shells closely shut.

I have enquired of those Fishermen, whom I thought men of reflection, what could be the reason why some years ago our flounders were very indifferent, and for these last three or four years so exceeding good ; for which they could not assign to me any reason ; but when I laid before them my sentiments respecting these fish being fattened by feeding on the small shell-fish, they were surpris'd thereat, and added, that this might very probably be the case. But upon conversing with two principal merchants who send out fishing-vessels, they not only agreed with me in my opinion, as before related, but also in the following, namely, that not only the flat-fish feed so much on the small shell-fish, but the whiting is so abundantly nourished by them, that in the summer-time its flesh becomes hard and tough ; for this reason, at the time when the shell-fish abound on our shores, the whiting resorts thither in quest of them, and this latter is followed by the cod-fish, which preys on the whiting. In short, I conclude that the plenty of fish found on our coast, proceeds from this cause only, the great quantities of shell-fish which every year breed there.

Towards the end of the month of February, being the first time in the spring that Muscles were brought to our city for sale, I caused some of them to be bought, in order to make my observations thereon : I found these to be very lean, and for a long time my search after their spawn was fruitless, though I could not think that the time was past for their depositing it.

Upon examining that part of the Muscle which is called the beard, I not only found it of a wonderful make, but the motion I saw in the small component parts of it was so incredibly great, that I could not be satisfied with the spectacle; and it is not in the mind of man to conceive all the motions which I beheld within the compass of a grain of sand.

When I observed the large and strong tendons or sinews in the Muscle, which are fixed to the shell, and those which lie in the same order and position as the ribs in a terrestrial animal, I thought that we cannot sufficiently admire the wonderful make of this fish; and that if we could obtain an insight into all those parts which we see in one of them, and could we assign their several uses, and give them names, and also make drawings of them, I doubt not that we should admire so elaborate and curious a work, beyond many others of nature's productions; and that those persons who now assert that shell-fishes (among which the Muscle is in least estimation) are produced spontaneously, or of themselves, would renounce their opinions, and embrace the truth, namely, that so perfect a creature cannot be produced from corruption, congealed water, or mud, but can only be generated by parents of its own species.

I observed that every Muscle was provided with a kind of string or ligament, which, at a little distance from the fish, was divided into 8, 10, 12, 15, and even 20 other ligaments of different lengths; and with these ligaments, I observed, that the Muscles fastened themselves to other Muscles, and also to pieces of shells, and to shell-fish of other species.

I was desirous to know how this fastening was effected, and which I immediately discovered; for I saw, to my great surprise, that the extremity of every ligament was provided with a thin flat membrane or skin, of a roundish shape, which was as firmly fixed to

the shell on which it was placed (the ligament being in the middle of it,) as if it were glued to the shell; and when I endeavoured to pull off the ligament, I found, by several trials, that (though it was very strong and tough, in proportion to its size) it would break before the flat thin membrane could be loosened.

Hereupon I recollected, that when a boy, I had often amused myself with a play-thing which we called * “ een Treck-leertje.” This is a small round piece of leather, about two inches in diameter, having a small hole in the middle, through which was drawn a pack-thread, with a knot at the end. This leather being first soaked in water, was placed flat on a stone, and with this we could not only lift up the stone, but carry it to some distance.

Now, upon the same principle as the stone adheres to the leather, partly by the pressure of the atmosphere, and partly because no air or water can gain admittance between the stone and the leather, the like effect is produced in the cohesion or sticking of the membrane I have been describing.

I have thought it proper to give a drawing of the ligament before-mentioned, and its several branches: and in Plate III. *fig. 8*, is shewn a part of it, which is cut off at A in the part which comes out of the shell; this in *fig. 7*, is shewn at BE of its natural size. In *fig. 8*, FGHK are seen the ramifications or branches, or rather a small part of them; and at LM is shewn one of the short ligaments, with its membrane NOP, the ligament here appears on the upper side of the membrane, in like manner as if the latter was fixed to some other shell; and here are to be seen the many parts whereby the ligament is joined to the membrane, which latter also appears somewhat elevated at the place of joining.

* That is, in English, a pulling or drawing-leather; it is a common play-thing among boys in England, and is called by them a sucker.

At Q R is represented another ligament, and at S T V its membrane, with the concave part of it, appearing open, being in a contrary position to the former representation. I have often seen this cavity reach into the ligament as far as M or R, but otherwise it is quite close and compact.

Each of these ligaments consists of a great number of excessively small particles, which cannot be contemplated without the greatest admiration, especially when we recollect the power which the Muscle has of moving each of these ligaments, and also that the membrane must be placed quite smooth and flat upon the shell, to which it is fixed, in order to cause it firmly to adhere thereto.

Now, if we farther consider that Muscles, while in the sea, always lie with that shell upwards which they open occasionally, and that their shells (which are very thin) and their bodies together are but little heavier than the water wherein they live, and also that many of them at low ebb-tides are left destitute of water, at which times, in my opinion, much air must insinuate itself between their shells, by which means they become lighter than the water; they would then be liable either with the ebb to be carried out into the deep, or by the flood to be thrown upon the land, and so would perish. But provident Nature has taken care to preserve them in this respect, by furnishing them with a ligament, spreading into various branches, and at the end of each branch an organ, which I have named a membrane, by the help of which the Muscles can fix themselves either to empty shells, or other substances, or to one another, by which means they are preserved.

But as my principal design was to discover, as far as possible, the generation, or procreation, of these fish, I come now to that part of the subject.

I observed, that these Muscles, some in a greater, and others in a less degree, had the outsides of their shells covered with a kind of substance, thinly spread upon the shell, and firmly adhering to it, or

rather to the membrane which covered it. Observing this by the microscope, I saw that the particles of which it consisted, were all of a similar form, and also placed side by side, in regular order, and the membranes or skins of these particles, as it were, united, or closely joined together. I separated a part of this substance from the shell and placing it before the microscope, I found that all the regularly disposed particles were much longer than they were broad, also that one of their edges was roundish and thick, the other terminating in a point or edge, and moreover that in many of them one side was rising, and the other flat; in a word, many of these particles, in shape, were very like a Muscle; and I not only thought that they were the eggs or spawn of the Muscle, but I also observed, that when I broke the strong membranes inclosing them, several of the eggs, which were in shape like a Muscle, appeared lying singly and separately on the outside of that membrane; and when I separated these unformed Muscles singly, one from another, I imagined that I could see the membranes or tendons of which they were composed.

I also saw the shells, membranes, or coverings of several eggs which were empty, and which I saw, or more properly speaking, imagined to be barren eggs. In other parts of this substance I saw eggs wherein I concluded that there were unformed Muscles, which conclusion I gathered from the multitude of vessels which I saw, which vessels constituted the shape or figure of a Muscle.

These eggs were not larger than a grain of common scowering-sand.

Moreover, I observed, that the small or taper ends of the shells were seldom or never covered with the spawn or eggs, the reason of which I took to be, that at the time the Muscles emit their spawn, they lie with the flat and broad part, as shewn at *fig. 7*, A B C D, uppermost, and that part marked with the letter A, next the ground, or bottom; for I have often observed that when Muscles have

been cleaned and put into a vessel of water, and an handful of salt thrown upon them, many will be soon found placed in the position I have mentioned; and while they lie in this position, and the eggs are put forth from the part marked C D, there must necessarily be more eggs lodged near that spot, than towards the farther end of the shell.

Several of these Muscles I placed in my study, in two glasses of water, with some salt sprinkled on them, in order to examine them daily, and see the progress of growth in the young ones; and upon this occasion, I could not sufficiently admire the exact and regular order in which the eggs were in many places disposed, just as if they had been so placed by men's hands; and from hence I was convinced that Muscles do not, like many other fishes, lay their eggs promiscuously, but that they must be furnished with some kind of organ, which they can project beyond the shell, and with it dispose them so regularly.

I have before said, that I thought I saw a kind of finews or tendons in the eggs; and upon further examination, I perceived sixteen of these tendons, like streaks, in the unformed Muscle, and among them I saw some still smaller streaks, from whence I concluded, that they were in fact, vessels to form the substance of the future shell, for they lay all in one direction, that is, from the small end, spreading or diverging round about; and they were thickest at that part, and thinnest at the extremities, spreading wider towards the broad and thin end of the shell: I caused a drawing to be made of a few of the eggs, in the order they lay on the parent shell, and as they appeared through the microscope; this is shewn at *fig. 9*, A B C D E, representing eight of them, in some of which it may be seen that one side is more curved than the other, and in which eggs may also be seen the finews, vessels, or streaks I have mentioned.

Upon considering that the lobster and the shrimp carry their eggs

about them until the young are perfectly formed, it seems probable to me, that this is also the case with the Muscle, for otherwise, how could this species of fish be propagated? especially if we consider that they lay their eggs in the middle of winter, and are generally in shallow waters, where the shore is muddy; and if the eggs were not deposited on the shells, they would be buried in the mud, with the common flux and reflux of the tide: not to mention that in stormy weather they would be carried out to sea; but while they are fixed to the shells of the parent, and these last adhering to solid substances on the shore, the eggs are, by this means, in great numbers, preserved; and these young Muscles, when come to such maturity as to be separated from the shells, may, in windy weather, strong tides or currents, be easily carried to other muddy shores on the coast, in places where for many years before no Muscles were to be found.

I have made a rough calculation of the numbers of these eggs, and I compute that there are frequently more than two thousand fixed to the shell of one Muscle; in fact, I have seen Muscles, each of which I judged had more than three thousand on it.

I have before said, that the eggs of Muscles are the size of common scowering-sand, but as this is not of the same size in all countries, I compute that, to the best of my judgment, seven of these eggs, in breadth, are equal to the fifteenth part of an inch, consequently the breadth of 105 eggs, is equal to one inch; and I also compute, that sixty eggs, in length, make an inch; therefore a square inch will contain 6300; and as each egg is no thicker than broad, 105 of them must lie one on another to make the thickness of an inch; the sum total then of the eggs which will be contained within the space of a cubic inch, is 661,500; and hundreds of such eggs may lie under shells, sand, or mud, without being perceived, and yet Muscles be produced from them.

Having taken some of the unformed Muscles out of the eggs, I

caused a drawing to be made of their figure, as near as the Engraver was able to imitate it; this is shewn at *fig. 10*, F G, which represents such an unformed Muscle, inclosed in its membrane, or covering, in which the streaks before-mentioned, did not appear, until the greatest part of the moisture thereof, was evaporated. *Fig. 11*, H I K, shews another of them, the streaks, or vessels in which, between I and K, appeared separated, or sundered from each other; and this was done in the taking it out of the egg, being in that operation deprived of the surrounding membrane, or skin.

At the latter end of April, when I had finished the preceding observations, I received a large jar full of Muscles out of Zealand; upon examination of which, I was much surpris'd to see that most of the shells were quite smooth and polished, being not only destitute of eggs, but for the most part, bare of the membrane, which gives them a blackish colour, so that they now appeared of a lively blue; however, I found four or five with perfect eggs on them, and in them were young Muscles; some of these I took out of the eggs, and now plainly saw, that what I had at first taken for the unformed Muscle, was, in fact, only the ligament, or string, whereby the young Muscle was nourished. A drawing of the real shape, as it now appeared to me, is given at *fig. 12*, where G H I represents the ligaments of the unformed young Muscle, and I K the Muscle itself; another of them is represented at *fig. 13*, where L M shews the strings or ligaments, and M N the Muscle; and this last figure, I think, exhibits the true form of the young Muscle, as it lies in the egg; and from these last observations it appears, that the parts represented in *fig. 10*, at G, and in *fig. 11*, at H, were only the substance, or matter, from whence the Muscle would be formed, and which, at the time when that drawing was made, had not come to sufficient perfection to render the parts distinguishable.

Now, since we see, that the eggs of Muscles adhere so long to the

shells of the parent, before they are perfectly formed, and also consider that during all that time they must be supplied with nourishment, we shall not wonder that the parent Muscles, during that time, do become lean, especially in the month of April, for then the young are most in need of sustenance.

We may also here observe, that in our enquiries after any truth, and more especially in regard to the generation of small living creatures, which cannot be examined by the naked eye, we ought not to rely on any tales that are told on these subjects, but on our own experience, and even that not lightly, but by long and unwearied trials and experiments, whereby to come at the truth.

In the course of the last observations, I examined that hard and variegated, or marbly-coloured part, lying in the middle of the Muscle, which some call the heart, and others take to be the tongue of this fish; and when, upon the Muscle, I cut out this part, and placed it before the microscope, I observed so tremulous or quivering a motion in the surface, as if millions of little living creatures were running about upon it; besides another motion, which the part had to and fro. This part the Muscle can extend so far, that I think it will almost reach all over the shell, which made me think that, perhaps, by this organ, the eggs are placed on the shell in the regular order I have before described.



(88)

Of the Muscle which is found in fresh water ; a particular description of its internal formation, and of the manner in which its young are produced.

I HAVE observed, that when our navigable canals here in Holland, or our ditches are cleaned, a kind of large fish are taken from the bottom, named by us, “ * Veen Mosselen,” or Peat Muscles. Of these I procured some, which were about three or four inches long with very thin shells.

A countryman, whom I saw collecting these shell fish, told me they were to be found under the banks, and in the shallow parts of the ditches, or canals, among the leaves and twigs, or other litter ; and, indeed, I have seen them taken in those places ; but as I was certain that these shallow places were frozen to the bottom in the winter, which the shell fish could not survive, I was told that they had a power of moving from place to place.

To satisfy myself, in this respect, I made two experiments on these Muscles, of which I put six or eight into an earthen vessel, with a flat bottom, and poured on them some of the same water in which they were taken ; this vessel I placed in my study, and I found that in a few hours time, they had all changed their positions, and had approached nearer together, than they were when first placed in the vessel.

* This word, “ Veen, ” means the Turf or Peat, which is dug up in great quantities in Holland, and is their principal article of fuel. Our author has a very ingenious dissertation on the origin of this substance, a translation of which will be found in its place.—These fresh water Muscles are found in the rivers in England.

And I observed, that these Muscles, about the middle of their shells, thrust out, through the opening, a fleshy substance, or organ, about two-third parts the length of the shell; this part was about half an inch broad, and sharp at the end; and in order to move themselves from place to place, they thrust this organ under their shell, and applying it with a quick motion to the bottom of the place where they lay, could by this means not only change their posture, but turn themselves upside down.

At the end of the month of August, upon opening six of these Muscles, I found many eggs within them, which were so perfect, that I could distinguish the newly formed shells, so that they were not so properly to be named eggs as unborn Peat-Muscles. Two of the parent Muscles were so small, that I judged they were not above a year old, whereas the others were, in my opinion, six, eight, or nine years old; but the young Muscles were of the same size in all of them.

In the beginning of September, I procured about fifty more of these Muscles, and upon opening twelve of them, I found two wherein the young ones seemed to be so perfect, that they would probably soon be excluded from the parent. I always found that the eggs were first formed in the fleshy part of the Muscle, but as they advanced in growth, they were moved to that part which, in oysters, is called the beard, and which, by the great number of the young Muscles contained therein, then swells in bulk.

As there are many persons who are unacquainted with this species of Muscle, and others who may wish to investigate the particulars of my observations, I have caused the following drawings to be made:

Fig. 14. G H I K L, shews one of these fresh-water, or, as I call them, Peat-Muscles, of the ordinary size, which is opened so as to leave the whole of the fish lying in one of the shells; at H I K, is represented the empty shell, and at M M, the two tendons, or sinews, by the help of which the fish shuts and opens the shell; and here it

is to be noted, that these fishes, by reason of the length of their shells, are each provided with two of those tendons, or sinews, whereas oysters and salt-water Muscles have only one. N O P is a thin membrane, or skin, lying folded up, with which the whole inside of the empty shell had been covered, or lined.

Q R S is one of the two receptacles wherein the eggs, as they advance to maturity, are lodged, and which parts do then become swollen thereby, but at other times they are very thin; these parts, in oysters, are called the beard; T V is the other of these receptacles, which, in oysters, is also called the beard; and in these receptacles, I did not observe any thing particularly remarkable, except their wonderful make.

W X Y is a solid fleshy part, wrinkled on the outer edge, and in respect of the other parts of the fish, very strong; this part, as I have already mentioned, the Muscle protrudes, or thrusts out of its shell, to a considerable length, when it prepares to change its place; and when at rest, it generally has a small portion projecting out of the shell; but if it be touched, though very lightly it immediately withdraws it. The spot marked with the letter Y, is the place where the eggs lie before they are deposited in what we call the beard; and if an incision be made in this part, the eggs, with a watery liquor, issue forth.

Some of these Muscles I opened in the presence of the Engraver, in order, that as soon as I had taken some of the young ones out of their receptacles, he might make a drawing of them, for, were they suffered to stand but a few hours, their true figure would be lost. The unborn Muscles being put into a glass tube, and placed before the microscope, I saw with astonishment a most pleasing spectacle, for every one of them, each in its particular membrane, or covering had a slow circumvolution, and that not for a short space of time, but such turning round or rotatory motion was observable for three hours afterwards, and it was the more curious, because the young Muscles, during the whole of their motion, constantly kept in the

centre of their membranes, just as if one were to see a sphere or globe revolving upon its axis. This uncommonly pleasing spectacle was enjoyed by myself, my daughter, and the Engraver for three whole hours, and we thought it one of the most delightful that could be exhibited.

Fig. 15. A B C D E exhibits fix of these unborn Muscles inclosed in their respective membranes; they were drawn by the Engraver in the most accurate manner he could, while they were in motion. Of these, I computed that each parent Muscle contained some thousands.

I had at the same time some unborn Oyfters before a microscope which I had taken out of the parent Oyfter five weeks before, and as they still appeared perfect in shape, I caused a drawing to be made of them also, and this is shewn at *fig. 16*, F G H I. In some of these the openings of their shells were plainly to be discerned.

These young Oyfters bore the most exact resemblance to full grown ones, though they were so minute that one hundred of them laid together would not equal an inch in length, and I have computed that each parent Oyfter contained three or four thousand of them.



(99)

On the Circulation of the Blood ; that it is not discoverable by the sight, in an human body, nor in the bodies of terrestrial animals : the same completely seen in fishes, and the nature of it particularly described.

THE Blood is composed of exceeding small particles, named, globules,* which, in most animals, are of a red † colour, swimming in a liquor, called, by physicians, the serum ; and by means of these globules the motion of the Blood becomes visible, which otherwise would not be discoverable by the sight. These particles, or globules, are so minute, that one hundred of them, placed side by side, would not equal the diameter of a common grain of sand ; consequently, a grain of sand is above a million times the size of one such globule.

I have often endeavoured to view the circulation of the blood in terrestrial animals, but without success, by reason that no parts of their bodies were sufficiently transparent. Among others, I tried the experiment with a young Cock ; which I wrapped in a cloth, in order to keep him quiet, leaving out only his head ; and inspected his comb, but could not therein perceive the motion of the Blood :

* Later writers contend, that the particles of Blood are not spherical, as this word imports, but plane, or of a flat shape ; and this Mr. Leeuwenhoek admits to be true with regard to fishes. However, the word globules is always used to denote the component particles of the circulating fluid.

† In some fishes the Blood is not of a red colour, and also in many insects, which have been therefore improperly denominated exsanguis, or bloodless.

I afterwards examined his gills, or those parts hanging under the throat, and there I saw it running in an inconceivable number of vessels; many of which were so minute, that numbers of them taken together would not equal the size of a single hair: but it was impossible for me to trace the circulation in them, by reason of their immense number, crossing each other in all directions: for the redness which we observe in a cock's comb and gills, proceeds entirely from the great number of blood-vessels on their surface, where they are only covered with a thin transparent skin.

After this, I made my observations on white Rabbits, by placing their ears before the microscope; but, with all my pains, I could not do more than see the Blood running with great swiftness through the arteries and veins. When I plucked off the short hairs from the extremities of the ears, because they obstructed my sight, I observed, that the pulling off each hair had broken or injured several of the vessels, and caused an effusion of blood. From hence I gathered the reason, why I had perceived that the pulling out any hairs from the back of my hand produced a redness in the part; and I now concluded, that we cannot pull out a single hair from any part of our bodies, while such hair is growing, without injuring some vessels, so as to cause the Blood to start.

But my greatest expectation of success, was placed on a Bat, because I conceived that the membrane, or skin, which serves this animal for wings, must be so thin and transparent, as to afford a view of the vessels. And, having procured one of these creatures, I put it into a glass and examined it by the microscope. Here I saw the motion of the Blood, both in the arteries and veins, most distinctly, and fully to my satisfaction, though by no means so clearly as is to be seen in fishes; first, because the membrane composing the bat's wing, is not so transparent; secondly, because there is more of the watery part (or serum, as it is called) in the Blood of fishes than in terrestrial

animals; and thirdly, because the particles of blood from which its redness proceeds, appear much larger in fishes, they being of a flat and oval shape; whereas, on the contrary, as far as I could judge from my eye, they, in this animal were spherical. I used every means I could devise to see the compleat circulation of the blood, namely, that one of the smallest of those vessels which we call veins, arose from another which is called an artery, and afterwards conveyed its contents into a larger vein; but this I found to be impossible, for when I followed the course of the artery, until it became so small as only to admit one or two globules to pass through it at a time, I then lost sight of it. If this artery, throughout its circuit, had not been smaller than the twenty-fifth part of an hair, I do not doubt that I could have seen the whole circulation; but as these vessels were at their extremities diminished to a much less size, and the membrane of the wing was covered with a kind of scales, I could not (as I have before said) follow with my eye those minute ramifications. I perceived, however, in many places, an artery and a vein, placed close beside each other, and of a size large enough to admit the passage of ten or twelve globules of blood at the same time; and in this artery the blood was protruded or driven forward with great swiftness, and flowed back through the vein, which was a most pleasing spectacle to behold.

I could also most plainly perceive in the arteries, the rising, or pulsation, caused by the motion which the blood receives from the heart; these pulsations were so rapid that I judged seven strokes were performed in a second of time.

The worm, or small animal which is produced from the spawn of frogs, and is called a tapdole, afforded me a still more distinct view of this subject; for, upon placing one of them, which was newly hatched, before the microscope, I could distinctly perceive the whole circuit of the blood, in its passage to the extremities of the vessels, and in its return towards the heart. But I must here observe, (as

before mentioned) that if this blood had been an uniformly clear liquor, its motion could not by any means have been discovered; but as it consisted of a very transparent fluid, mixed, as it seemed, with globules of different sizes, which were plainly to be distinguished, though they had not, as yet, in this creature acquired any colour, the circulation was thereby rendered very apparent.

When these tadpoles were about eight or ten days old, I could perceive a small particle moving within their bodies, which I concluded to be the heart; and the fluid which was protruded from it began to assume a red colour.

Upon examining the tail of this creature, a sight presented itself, more delightful than any that my eyes had ever beheld; for here I discovered more than fifty circulations of the blood, in different places, while the animal lay quiet in the water, and I could bring it before the microscope to my wish. For I saw, not only that the blood in many places was conveyed through exceedingly minute vessels, from the middle of the tail towards the edges, but that each of these vessels had a curve, or turning, and carried the blood back towards the middle of the tail, in order to be again conveyed to the heart. Hereby it plainly appeared to me, that the blood-vessels I now saw in this animal, and which bear the names of arteries and veins, are, in fact, one and the same, that is to say, that they are properly termed arteries so long as they convey the blood to the farthest extremities of its vessels, and veins when they bring it back towards the heart. For example, I see many blood-vessels in the tail of a tadpole taking their course, as represented in Plate IV. *fig.* 1. ABC, where the position of the parts A and C is towards the spine or middle of the tail, and the part B towards the edge of it. In A B, the blood is driven from the heart, and in B C, it is brought back again, and thus may we say, that the vessel A B C, is both an artery and a vein, for it cannot be denominated an artery, farther than where the

blood is driven in it to its farthest extent, that is, from A to B; and we must name B C, a vein, because, in it, the blood is returning back to the heart. And thus it appears, that an artery and a vein are one and the same vessel prolonged or extended.

In the part where I saw this circulation, the arteries were no larger than to admit a single particle of blood to pass freely through them: these particles, though in this creature they were of a flat and oval shape, yet sometimes by reason of the smallness of the artery, assumed a kind of oblong round figure, and when the animal, by being taken out of the water, grew languid, the blood in these very minute arteries began to stagnate, and when it again acquired motion, many of the globules appeared twice as long as broad, and also pointed at their extremities.

In another place, I saw a larger artery divide itself into two branches, which are shewn at *fig. 2.* D E, and each of these branches returned back with a curve, as represented at E F and E G. Now, if we denominate D E F, and D E G, arteries, because, in them the blood is driven outwards from the heart, it follows that F H, and G I K, must be veins, because they each bring it back towards the heart. Again, not far from K, was another smaller artery, which is figured at M L; this was united to the vein I K, so that the arteries D E G, and M L, together formed one vein at I K. In a word, in this figure, H F is a vein, D E F and D E G, are arteries; G I K and K I L, are veins, and M L is an artery; and yet we must say, that these are only the same vessels continued.

In another place I saw three of the smallest arteries, after returning in a curve, as before described, unite in one, and thus form a vein three times the size of each artery. But all these three vessels with their bendings wherein the circulation was performed did not occupy more space, than could be covered by a grain of sand.

I often perceived an artery, taking its course over, or crossing

a vein, and, if a person did not clearly see the different courses of the vessels, he might conclude that here the circulation was performed or compleated, and this I saw not only in the smallest vessels, but in those which were ten times larger. This transverse course, or current of the vessels, I had often before observed in terrestrial animals, whilst I was endeavouring to discover the conjunction of their arteries and veins. But, as I became then well assured, that this conjunction, or circulation, did not take place in the larger vessels, but in the very smallest of all, (for otherwise I am persuaded, that all the parts of the body could not be supplied with nourishment) and that therefore I should in vain attempt to discover such circulation, I, some years ago, abandoned the farther investigation of it. For, if we now plainly perceive, that the passage of the blood from the arteries into the veins of the tadpole, is not performed in any other than those vessels, which are so minute as only to admit the passage of a single globule at a time, we may conclude that the same is performed in like manner in our own bodies, and in those of other animals. And if so, it must be impossible for us ever to discover the passage from the arteries into the veins in the human body, or of any terrestrial animal; first, because a single globule, when lying in one of those minute arteries, has not any visible colour, and secondly, because, in those vessels which are so large as to come within our sight, the blood has not any perceptible motion.

The particles in the blood of frogs are (as before observed) of a flat and oval shape, and these, when viewed singly, appear, as I may say, colourless; but when two are laid on one another, they appear a little of a reddish cast; and where three are together, the redness becomes deeper. This may be explained by *fig. 3.* wherein A represents one of these oval particles, which, in part, is covered by another particle B; and C is a third particle, covering a small part of both A and B; by which means the part at D, where the particles are three-fold, acquires a still darker colour. But when

I have attentively examined one of these oval particles on the edge, as is seen at E, I have found it exhibit a stronger blood-red than where three particles lay flat one on another.

Among the tadpoles, which I caused to be taken out of the canals, I perceived a few very small fishes, having their skins marked with dark spots, some of which were of the figures of little stars. This species of fish I judged to be of its full size, because I had never seen any by the naked eye of the same shape as these appeared when magnified. One of them I placed before the microscope, and, upon observing the finny part which constitutes the extremity of the tail, I plainly saw the same kind of slender arteries and veins as I have before described, though with more difficulty than in the tadpole, partly, because this fish did not long continue quiet, and partly because the particles of Blood (which, in these observations appeared to me no other than globules) were much smaller than in the tadpole. These arteries and veins were placed near the boney parts, or risings, which give strength to the fin at the tail, and in them I saw the compleat circulation of the Blood; for, on both sides of each of the before-mentioned boney parts was an artery, which had a bending, or backward turning at its extremity, and thus became the beginning of a vein.

Upon viewing this fish's tail, at the part where the fin begins, I there saw, to my great admiration, a large artery dividing itself into the before-mentioned smaller ones; and close to it, numbers of the minute veins returning from the fin, and uniting in one large vein. In short, here was such an agitation, or motion of the Blood driven out of the large artery to the farthest end of the tail and into the fin, and running back in the small viens, into the large one, as is inconceivable.

In order to shew the size of this little fish, wherein I observed all these motions of the blood, I caused a figure of it to be drawn, as it appeared to the naked eye, and this is shewn in Plate IV. *fig. 4.* At

fig. 5, is shewn part of the body and the tail of the same fish, as seen through the microscope. DE is a fin on the back, and LM, another under the belly, near the tail, and FGHK is the fin of the tail, wherein are to be numbered seventeen small bones.

These small bones, contrived by Nature to give strength to the fin, were formed with joints; and I could see that they were composed of oblong particles, which, probably, were hollow tubes; the pellicle, or membrane, which covered them, and composed the greatest part of the fin, was also formed of oblong parts, but these things the limner could not perceive, because the fish being then dead, they were become invifible.

I have before said, that on each fide of these boney parts of the tail I had distinctly seen the compleat circulation of the blood, and this was in thirty-four places, two between each bone; that is, there were in this fish's tail fixty-eight blood vessels; namely, thirty-four arteries, and as many veins, besides those vessels that, probably, were in the smallest part of the fin, about F or K, which I did not attend to.

To shew this circulation more plainly, I caused one of the boney parts of the tail to be drawn somewhat more magnified, which is represented at *fig. 6*, OPQR. Close to each fide of this bone lies an artery, which in the figure is pictured at ST and WX, and in these vessels are represented the particles of blood, which appear of a round figure. Here the blood was to be seen running with a swift course from S to T, and with the same swiftness returning back from T to V, so that ST is an artery, and TV a vein, and yet, both of them but one blood-vessel, continued and prolonged. In like manner, were the blood-vessels on the other fide of the bone at WXY. But these arteries and veins were not at so great a proportionate distance as here represented, for, in many places, they were so close as to touch each other.

In other places, and also in the two fins D E and L M, I saw the blood not only running along, but also taking its whole course forward and back again, in manner before described.

Now, if in the tail of so small a fish, as this which is pictured at *fig. 4.* there are to be found thirty-four distinct circulations of blood, what an incredible number of them must there be in an human body ! And this being so, it is no wonder, that, upon the least puncture made by a needle, or any other small instrument, the blood issues forth. Indeed, from these my observations, I am well assured, that, in the space of a finger's nail, in any part of the surface of our bodies, there are more than a thousand circulations of blood.

Some years after these, and other observations of the like kind, had been made by me, I accidentally fell into conversation with a certain learned Gentleman, (not a native of Holland) on this subject of the circulation of the blood, particularly in the minutest vessels which are contained in a very small space, and that this circulation could as plainly be seen, as with the naked eye we see water springing up from a fountain, and falling down again ; but though I used all my endeavours to convince him of the truth of what I advanced, yet this learned Gentleman refused to give credit to my words, declaring that he could not form any conception of the matters which I related.

This Gentleman's incredulity took up much of my thoughts, particularly upon a time when I had got some very small eels, not longer than one's little finger : and on this occasion I sent for a limner, who I knew was a very curious observer, and had a very acute sight, judging that he would be able to make a drawing of some of those blood-vessels.

I then put one of these small eels into a glass tube, about the size of a goose-quill, and placing it before the microscope, I delivered it into the limner's hands, desiring him particularly to attend to the current of blood which at that time was most distinctly to be seen in

some small vessels ; desiring him, at the same time, to observe, that all those vessels through which the blood was driven outwards to the extremities, were named arteries, but where the blood, when arrived at the smallest vessels, began to take its course back again, there they were called veins, although it plainly appeared that the vessels were one and the same.

The limner could not sufficiently admire this spectacle of the blood circulating in such minute vessels, arising out of the larger ones ; and he was equally in admiration at the blood's returning from those very small vessels into the larger. And as the eel continued quiet longer than usual, without moving its tail, I frequently desired the limner that he would, as long as possible, keep his eye fixed on this current of the blood, in order to imprint the idea on his memory. At length, he put his hand to paper, and made a rough sketch of some blood-vessels and their ramifications, or branches ; and he repeated his observation and his drawing, until he had completely traced six several blood-vessels, namely, three arteries, and as many veins, with their ramifications, with all the accuracy he was able, saying, he had now sufficient materials to make a perfect drawing, so as to describe the exact proportion both of the larger and smaller vessels.

In Plate IV. *fig.* 7, and in the space between 1, 2, 3, 4, are represented six of these blood-vessels, which I directed to be drawn on rather a larger scale than the first sketch taken of them, in order that the several vessels might be easier distinguished ; therefore this figure shews them about twice as large as they appeared to the limner through the microscope.

These vessels were not at the very extremity of the fish's tail, but a little below it, towards the end of the fin. And that part, or spot, which the limner saw through the microscope, and the several blood-vessels of which he made the drawing, did not, in my judgment, take up as much space as is occupied by a large grain of sand ; for though the view of the microscope might include the compass of four such

grains, yet the part wherein the blood-vessels were seen, did not amount to a fourth of that space; so that, within less compass than that of a grain of sand, there are found to be in the tail of an eel, as great a number of blood-vessels as are here represented between 1, 2, 3, 4.

At the letter A, is represented one of those blood-vessels, which are called veins; B, one of those named arteries; C, is a vein; D, an artery; E, another vein, and F, another artery.

But, in order more clearly to explain the course of the blood in these vessels, and to shew, at what part, though in fact they are one and the same, they assume different names, I have in the figure more particularly pointed out, and shall now describe one of those vessels called an artery.

D, is that artery, out of which, at G, proceeds a small branch, which, at H, divides itself into two, as HIK: and here we see, that the branch GHI is properly to be named an artery, because, as far as I, the blood is driven from the heart, and IK, we must name a vein, because, from I to K the blood is brought back towards the heart. In the other branch, which proceeds from H, in the direction HLM, the blood is infused into the vein E at M; and since at M it first begins to take its course towards the heart, it follows that at M this vessel first assumes the name of a vein.

In this small artery GH, it is to be observed that the limner has been very accurate in describing the exact size of the vessel, and we must always bear in mind, that in these branchings, or ramifications, the arteries grow smaller and smaller, and the veins continually grow larger, as they receive the blood from the arteries. Farther, all the minute blood-vessels described in this figure the limner has represented, not by lines, but by small circular dots, so as to give an idea of the particles or globules of blood, which he very distinctly saw, running or passing through them.

All the minute vessels which are represented in this figure, of the

size pictured at HIK, or HLM, are of equal dimensions, and they are so slender, that I can safely affirm, that if a grain of our common scowering sand were divided into a million of equal parts, each of those parts would still be too large to find a passage through these minute vessels. Which being considered, we may conclude how exquisitely slender must be the vessels in which the circulation is performed: and if it were not so, how could all the parts of our bodies be continually supplied with nourishment? *

Farther, in the before-mentioned artery D, is another small ramification at N, which deposits its contents in the vein E at O, and a little higher, at P, is a branch which unites itself with the vein E at Q.

At R, may be observed another small branch, proceeding from the same artery D, which, at S, is joined with a small branch from the artery B, and afterwards both fall into the vein C.

Again, at T, is another small branch, arising out of the artery D, which, at V, subdivides itself into two, and, in two several places, namely, at W and X, conveys the blood into the vein E, and from the same artery another branch arises at Y, which, at Z, is divided into two, and these are united to the vein C at the places marked *a* and *b*.

At a small distance from Y, is another very minute branch at *c*, which is joined to the vein C at *d*.

Farther, at *e*, another small artery branches forth from D, taking the direction *ef*, and at *f* is subdivided into two still smaller branches, both which join the vein E at *g* and *h*.

* A very eminent physician of our own country, (Dr Mead) expresses himself in very nearly the same words: "Every animal machine is of such a nature, that there is a
" sort of infinity in its constituent parts, by which expression I mean, that their fibres are
" so extremely small, that we cannot discover the ultimate stamina, even by the assistance
" of the best microscopes. Had it been otherwise, aliment could not be conveyed to
" every individual part of the body; nor could the necessary functions of life be per-
" formed.

MEAD'S *Medical Precepts*, in the *Introduction*.

A little higher in the artery D, a small artery branches off at *i*, proceeding to *k* and *l*, where it again divides itself into two, and joins the vein E at *m* and *n*.

Close to *i*, two small branches arise at *o*, and join the vein C at *p* and *q*.

At *r* arises another small artery *rs*, which at *s* divides into two smaller branches, one of them taking the course *st*, to join the vein C, and the other passing by *suwx*, to join the vein E.

Lastly, the extremity, or smallest part of the artery D, is shewn at *ryz*, and is united to the vein E at A, first sending off a branch near the letter *u*, which taking the direction *ub*, is united to the vein C at *t*.

Hence it plainly appears, how many various branches or minute arteries proceed from those small blood-vessels, or arteries, represented at B, D and F, and how these all unite with the other small vessels called veins, which are shewn at A, C and E; and this also proves what has been so often mentioned, that all these blood-vessels, though called by different names, are yet the same identical vessels. And if we reflect, that each of these very small vessels must be formed with the same kind of coat as the larger ones though of a thinness proportioned to its size; and farther, if we consider of what wonderfully fine and invisible membranes the coats of the smallest vessels must be formed, and how easily the finest part of the arterial blood may find a passage through those coats, to the end that every part of the body may, from thence, be continually supplied with necessary and suitable nourishment; these things, I say, being duly weighed and considered, it seems clear that the arterial blood, coming from the heart, must contain more subtile and fluid parts than when in its passage to the heart. For the blood will not be deprived of its more subtile juices, while in the larger arteries; to prevent which, I imagine that they are provided with thick and solid coats. And here the particles of blood from which its redness proceeds, swimming in a thin juice, are of a bright red colour; but

in the smallest arteries, some of its parts are drawn off for the support and nourishment of the body, whereby the blood, when returning in the veins, being deprived of those thin juices, assumes a darker red, and as more of the thin juices are taken away, it will appear blackish.

The circulation of the blood is represented in another view, at *fig. 8*, A B C D E F G H I K, which is a drawing of some vessels seen by the microscope, in the tail of a tadpole; these animals are much quieter than eels, and the arteries and veins are as easily to be seen in them as in any other creature; and in the smallest vessels where the period, or the retrograde motion of the blood is performed, its particles are more distant from each other than in any other animal.

The vessel, shewn in this figure, (which was an artery, wherein the blood was driven forward with great swiftness from A to B) was rather larger than to admit one of the particles of blood at a time. At B it divided itself into two branches, which are represented at B C and B E; these two branches were at D again united in one, for a short space, and at F they again separated, as shewn at F G and F I. Here these two arterial branches, making a small curve, or bend, again joined in one at H, forming a somewhat larger vessel, which is seen at H K; and at K, this was joined to a still larger blood-vessel.

Here it is plain, that the vessels A B C D E F G, and A B E F I, forasmuch as in them the blood is driven from the heart, to G and I, its greatest distance, must be named arteries; and the vessels G H K and I H K, because in them the blood is returning to the heart, must be named veins.

I formerly was of opinion, that in all cases where by an accidental fall or blow, there were produced livid or purple spots upon the skin, which proceeded from coagulated blood, this blood (if no exulceration should take place in the part) would by degrees be so dissolved, as to be carried off by perspiration; but the following observations caused me to alter my opinion in this respect.

In the tail of this tadpole, I observed a vessel, of a size to admit twenty of the particles or globules at once; so that this was a large vessel, in proportion to those which I have before described. A small part of it is represented at *fig. 9*, L M; and from this, proceeded a minute vessel, which is shewn at M O.

The current in this vessel, from L to M, was not so swift as I observed in the other vessels, and for this reason, that, in another part of it, at R, the blood was coagulated, inasmuch, that no distinct particles could be perceived in it, but only an uniform redness; but in the small vessel N, the current was as swift as in any of the others.

In consequence of this stagnation at R, the blood was driven forwards from M to P, with every pulsation of the heart, and instantly ran back again, in like manner, as if with the naked eye we beheld a swift alternate or reciprocal motion, like that of a saw.

We know, that water cannot be compressed into a less space than it naturally occupies; and this being also the case with regard to the blood, we must conclude, that the coat of this vessel, between N and P, and also a little below N, was, at every pulsation, expanded in diameter, and, at the intermitting of the pulsation, would contract itself, and so drive the blood back again.

Keeping my eye fixed on the object, I perceived, in a little time, the blood between P and R begin to move, and by little and little, from P towards R, to have the same alternate motion to and fro, as I have before described. At the same time, the blood in the vessel N S, where, at first, little or no motion could be seen, the current was now as swift as usual. And in the small blood-vessel, marked P Q, which was only of a size to admit one globule at a time, and wherein I could not at first discover any motion, the circulation was now restored; but the particles of blood were few in number, and at a distance from each other.

At length all the blood from P to R, was so far rendered fluid, that, at every pulsation, it was driven forward, and then returned back again. In these observations, about two minutes of time elapsed, and my eye being fatigued, I took it off the object to give it rest, in which interval, the animal put itself into a violent agitation, thereby precluding any farther observation.

But, since we now clearly see, that coagulated blood can, by the pulsation of the heart, in course of time, not only be put in motion, but also so far dissolved, that its component particles or globules may re-assume their pristine figure, we may fairly conclude, that blood, in any animal, which by a blow or bruise, is made to coagulate and stagnate in the vessels, may, in the space of some days, be restored to motion.

$$\begin{array}{r}
 60 \\
 75 \\
 \hline
 4500 \text{ an hour.} \\
 24 \\
 \hline
 18000 \\
 90 \\
 \hline
 108,000 \text{ a day and a night.} \\
 10 \\
 \hline
 1,080,000 \text{ ten days.}
 \end{array}$$

For, supposing, that in an human body, the blood is driven from the heart seventy-five times in the space of a minute (some say the number of pulsations does not exceed sixty, but I believe my computation to be nearest the truth) it follows, that the pulsations in an hour's time, are 4,500,

and, in the space of a day and a night, 108,000.

Now, if we find, that the appearance produced by coagulated blood, will, in the space of ten days disappear, from our bodies, and consider, that, in the same space of time, a million and eighty thousand pulsations are performed, and supposing, that, at every pulsation, so much of the blood is put in motion in the several vessels, as is only equal in size to a grain of sand, we may gather how much of stagnant blood may be restored to motion, in the space of time just mentioned.

For example, let us suppose, that the quantity of blood, which at every pulsation can be rendered fluid, and restored to its motion, is no more than the size or quantity of a grain of sand, and that eighty of such grains placed side by side do not exceed the length of one inch; we find then that 512000 grains of sand taken together are equal to a cubic inch, which number is not the half of the number above assigned.

80
80
6400
80
512000

In this blood-vessel, which I have just mentioned, I could not only very clearly discern the several pulsations, but I could also many times in all the arteries, see to make an exact computation how many times the blood was propelled from the heart in the space of one minute.

Now, if we consider that so great a quantity of blood, as is contained within the compass of a cubic inch, is very rarely by a blow or bruise congealed in one spot, we may easily conceive, that when a coagulation does happen, it may, by such frequent propulsions or pulsations as I have mentioned, be at length dissolved, and in all, or most of the vessels, restored to the same current or course as before.

At another time, I observed an appearance of a different nature in the blood-vessels, which was occasioned by my having put a tadpole into a piece of clean paper, whereby a small spot in the very thinnest part of its tail stuck to the paper, and thereby received a small injury, so that some blood flowed from the wound, out of an artery which was of a size to admit about four globules of blood to pass through it at a time.

The blood thus flowing out, remained collected about the wounded part; but here another sight presented itself, which engaged all my attention; for, in this same artery, at about the half of an hair's breadth distance from the wounded part, another small branch appeared, wherein the blood pursued its course in the same uniform and distinct manner, as if the artery had remained uninjured.

At *fig. 10*, T V, is seen this artery, which was wounded a little above V. The letters V and X indicate the extravasated blood. V W denote the minute artery in which the blood pursued its regular course, though close to the place, at P, it issued out from the artery T V.

This sight at first surprized me, but my wonder ceased when I observed that this blood vessel V W, was united with a large one at W, and of that sort which, carrying back the blood to the heart, is called a vein. And by means of this last-mentioned vessel, the blood was carried through the passage V W, as it were, by a kind of suction, with as much swiftness as it had been before driven from T to V, inasmuch that I was persuaded, that if the small vessel V had not been united to the artery T V, but only its orifice had laid in the extravasated blood, about the spot at V, that such extravasated blood would in a short time have been, as I may say, sucked up and carried away with the remainder of the blood towards W.

I have often reflected on the nature of those very thin transparent pellicles, or skins, which constitute the wings of small flying insects, such as gnats, flies, moths, and the like; some of which I have observed to be entirely covered with feathers, others composed only of those muscular parts which strengthen and expand the wing, and others are wholly covered with hairs: and when I considered, that these hairs, or feathers, are fixed or rooted in regular order in the membrane of the wing, my thoughts were wholly bent to discover how these wings might be formed.

As to the supposition which at first occurred, that these membranes were composed of a transparent viscous or gummy matter, congealed or hardened to a due consistence, I could not satisfy myself with that idea, for it seemed impossible to me, that in that case the feathers and hairs could be produced in such regular order; and yet, it was beyond my comprehension how so thin a membrane could be furnish-

ed with such a number of veins or vessels as would be requisite for the formation of such feathers and hairs.

In my endeavours to investigate this subject, I first examined one of those flying insects, whose wings consist of membranes only, without either hairs or feathers; which membranes are placed between the large vessels and sinews, giving strength and stiffness to the wings; and upon the examination of these, I plainly saw that there were large blood-vessels running among the sinews or muscular parts, from which arose smaller vessels, and these again divided themselves into still smaller ones, until at length they became invifible.

I was not, however, content with this, and among other objects, I met with a large green grasshopper, in the wing of which I more clearly perceived not only, that from the large blood-vessels in the wing, other smaller ones arose, but I also saw that the colour of the blood in these large vessels was green; and in the smaller vessels and their more minute ramifications, I could still distinguish the blood to have a greenish cast; but when these vessels were again subdivided into smaller ones, I could not perceive any colour in them, and the vessels themselves became so clear and transparent that they entirely escaped the sight.

Though I could most plainly see that the substance, or matter, of which this blood was composed, consisted of globules swimming in a clear liquor, I moreover cut the wing in two, and out of the vessels collected some of the blood, which I placed before the microscope, and observed that where the globules or particles of it lay in numbers or heaps together, the colour was a lively green, where they lay so thin as not to amount to the twentieth part of the thickness of an hair of one's head, the colour was only greenish, but where the globules were singly dispersed, it had no longer any appearance of colour at all, but became transparent; and here it clearly appeared

to me, that all these green globules were contained in a thin transparent fluid.

From these observations I concluded, that the transparent membranes which principally constitute the wings of these small animals, are as completely provided with blood-vessels, sinews, &c. as the bodies of other creatures.

I formerly was of opinion, that in the wings of these small flying creatures there was no circulation of the blood, for I judged, that in its passage through such exceeding slender vessels, it must be evaporated or dried up: and the rather, as many of these winged insects do not take any food, but only live a few days, and die as soon as they have coupled, and laid their eggs. But if we recollect, that the membranes of their wings are of a hard and horny nature, though exceeding thin, we may conclude, that all the vessels, composing this horny membrane are so firm and tough, that, though all the fluid contained in them should be dried up by the heat of the sun, the vessels themselves would not collapse or shrink up, as those in our own bodies, or the bodies of other animals would do in the like case.

I was confirmed in this opinion, by observing that the blood-vessels in the wings of these insects were not of the same make as those in the bodies of the human species and of terrestrial animals, but were composed of annular parts, or rings, like the windpipe and the vessels pertaining to respiration in the lungs of animals. And, though we may not be able to discover all these vessels in the wings of insects, yet we may be assured that there is an incredible number of them entering into the composition of those wings. And, should we imagine, that these vessels by reason of their smallness or their hard and dry nature, are impervious to blood and juices for the sustenance of the wing, we must consider that there is not a single hair or feather, how small soever it be, which is found upon one of these wings, but must have had in it many small vessels necessary for its production; for every feather has its quill and every quill must have a great num-

ber of vessels, in order to contribute to the increase of such feather : and who knows whether each of such small feathers may not have been formed out of more than a thousand vessels ? And when we reflect on the great number of feathers or hairs with which the wing of a fly or moth is covered, we shall find it impossible to conceive the numbers of vessels of which these insects, though they appear contemptible in our eyes, are composed. Indeed, I am of opinion, that many physicians and surgeons cannot reckon up so great a number of vessels in a cat or a dog, as I imagine enter into the composition of a gnat.

It was also at one time my opinion, that the ridges, or thicker parts, in the wings of these flying insects, and which I have named sinews, were only the boney parts of the wing to give it strength. But when I perceived, that there were large blood-vessels in those parts, I applied myself with all diligence to discover, if possible, the current of blood in those vessels.

For this purpose, I took those butterflies which proceed from the caterpillar that feeds on the aspen, the poplar, or the willow ; and which, in size and shape, resemble the silk worm's butterfly. Their wings are, on both sides, covered with white feathers, and, unless these are taken off, the membrane cannot be discerned. These feathers I wiped from the wing with a soft piece of leather, as gently as possible, to avoid injuring the wing or hurting the butterfly. And I then applied the wing (while the animal was alive) to the microscope ; but, with all my attention, I could not discern the least current of blood in the vessels, though if there had been any regular motion, I have no doubt but I should have seen it, and the rather, as this blood was of a yellowish colour ; and, upon opening the large vessels in these wings, I have often pressed out the blood which they contained.

For the most part, these large vessels lye in, or near, that boney part of the wing which gives it strength ; and I have often observed

those vessels to be placed, not in a right line, or parallel with the boney part, but twisted, with various turnings, in like manner as if one were to see the intestines of an animal in the posture they lie while joined to their membranes.

After this, I accidentally met with a large grey moth or butterfly, which in a manner flew into my hand. This butterfly I killed, and cut off the wings, and, having taken off the feathers, I placed them before the microscope: and here I saw the blood-vessels more plainly than in the wings of the other insects I have mentioned. A part of one of these wings I placed before the microscope, and caused a drawing to be made, not only of those blood-vessels lying in the boney part of the wing, but also of those which were dispersed over the membrane, and of which the membrane, in part, consists; in order to shew, how the vessels lye twisted in various turnings; also, how they are composed of annular parts or rings placed together; and likewise, how, from these large vessels smaller branches arise, which, in great numbers, are spread all over the membrane.

In Plate IV. *fig. 11.* P Q R represents a blood-vessel, with its various branches, spread over the membrane. A B C D E F G, is a large blood-vessel in one of the boney parts of the wing, wherein is seen, the manner how this vessel is twisted or bent, and also, the annular parts of which it is composed; in conformity with the formation of the blood-vessels in all insects; insomuch that I have seen the blood-vessels in the louse and flea, to be composed of such annular parts.

In the same figure, B H, I K, C L, D M, E N, and E O, represent the blood-vessels with their branches issuing from this last-mentioned vessel, and spreading over the membrane; and in these also, the annular parts could be distinguished; but when they became so small, as to appear no larger through the microscope, than a horse-hair to the naked eye, then the rings in them could no longer be discerned. These vessels the limner pursued in his

drawing as far as his eye could distinguish them, but at length they became so minute, and so intermixed one with another, that no true judgment could be formed of them.

In S T V, are shewn a few of the feathers, which so exactly cover both sides of the membrane, that no part of it can be seen. W W W, are three larger feathers which were placed on the edges of the wing. XXXXX indicate the membrane, when it was laid bare of its feathers, on both sides, in order to discover the blood-vessels. And here, though not in regular order, may be seen the cavities or holes in which the quills were fixed, and from which they had their origin.

Farther, I considered with myself, whether or no the blood-vessels consisted of arteries and veins; but I could not see any other than one sort of vessels in the wings of all the insects of this species, which I have examined, except that once I thought I saw in the thinnest part of the wing of a grasshopper, that in the larger vessels next the body, another species of vessels was inserted.

The conclusion drawn by me upon the whole was, that there was not any circulation of the blood in the wings of these creatures, and that the blood-vessels I have been describing, which certainly were arteries, were only designed to perfect the formation of the wing with its multitudes of feathers, and afterwards, to convey the blood, with an exceeding flow motion, through the vessels, in order to afford a small degree of support to the wing in its perfect state. For, as these butterflies, and those which are produced from the silk-worm, and many other flying insects which proceed from caterpillars, do not take any food, and do not live any longer than till they have coupled and laid their eggs, it is not necessary, in my opinion, that the blood in their wings should have any circulating or retrograde motion, and besides, the membranes being of a stiff horny nature, they require little or no nourishment.

I cannot here omit to mention, that I have heretofore often taken

great pains to discover two kinds of vessels in the leaves of trees and plants in order to ascertain, whether there was any circulation in leaves, but I never could see more than one species of vessels, namely those that convey the nutritive juices to the several parts.

But, if we consider, that not only the leaves of trees, but also their fruits, do not need any other than those nutritive juices, which are requisite to bring them to perfection, we shall not wonder that when at a state of maturity, they are, as it were, spontaneously loosened or shaken off from the tree, without the least appearance of having been broken off; nay, that part of the stalk which was originally united to the tree, will appear as smooth as if, with its multitude of vessels, it never had been joined to it.

In a word, I will venture to assert, that neither the wings of the before mentioned flying insects, nor the leaves or fruit of trees, require that kind of circulation of the juices, which we have been considering.



Of the formation of the Teeth in several animals; the structure of the human Teeth explained, and some of the disorders to which the same are liable accounted for.

HAVING taken great pains to investigate the formation of the elephant's tooth, and examined into the nature of it by every means I could devise, I found it to consist only of a collection of tubuli, or pipes, which are exceedingly small, and all derive their origin from the inner part of the tooth, for I never could discover any of them lying longitudinally or lengthwise in it.

Upon examining that part of the tooth where the boney substance is but thin, which is where it is united to the head, I very plainly perceived that one end of these tubuli took its rise from the cavity within, and the other end extended to the circumference, which circumference or outside was composed of a kind of scaly particles laid one on another, and I considered with myself whether each series or layer of these scaly particles might not be the substance or thickness formed in the space of one year.

Pursuing these my observations in the examination of that part of the tooth where to the eye it seems perfectly solid, I there found it to have, near the middle, a small cavity, through which cavity I concluded the nutritive substance must be conveyed, for the continual support and increase of the tooth. And upon examining the tubuli round about this small cavity, I perceived that they all arose from thence, and spread themselves all round towards the circumference. I endeavoured to examine still farther, beyond the part where this cavity ended, in order to discover whether from these first formed

tubuli others might not arise or branch forth ; but this part of nature's work was inscrutable to me. My conjecture respecting the matter however was, that each of the boney tubuli (proceeding from the small cavity before mentioned) might be composed of many folds or coats, and thus not only be disposed to diverge or spread into a larger space, so as to form the substance of the tooth, but also, by this means, contribute to its strength.

I also examined the teeth taken from young hogs, and found them to be likewise formed of tubuli spreading from the cavity in the center, to the circumference.

After this, I was desirous of examining the structure of the human teeth, and having for that purpose procured a number of the large ones, called the grinders, I found them to be formed exactly in the manner before described, namely, of tubuli or little boney pipes, closely joined together, arising at the cavity in the middle of the tooth, and ending at the circumference or outside. And in order to explain this formation to the Reader as clearly as possible, I caused the following drawings to be made :

In Plate V. *fig.* 1, at A B C, is represented a human tooth, on one side of which, with a file, I cut away almost the half, not to discover the cavity therein, which is well known to most persons, but only to shew the manner how the tubuli, of which the boney part is composed, take their rise from the cavity in the center, and terminate at the circumference. But it must be understood, that these tubuli are by no means of the size represented by the lines in this figure, the same only denoting the order in which they lie, for the tubuli themselves are exceedingly small, and cannot be well discerned without the help of the very best microscopes.

In the same figure, at G H I, is represented another tooth, which is filed down from the upper part of it as far as the before-mentioned cavity, in order to shew how the tubuli do here also spread themselves round about from the center. All the extremities of the

tubuli which lie near the outside of the tooth, (as far as they are above the gums, and exposed to the air) are extremely hard, being as it were the solid case, shell, or covering of the tooth : and if we examine the surface of this case or covering attentively, we shall find one tooth to have forty, another perhaps fifty circles on it, like wrinkles, or gatherings, which in some places run in a curved or wavy direction, as is represented in the figure at D E F, where a drawing is given of this outside shell, with some of the circles marked thereon ; and I imagine that the circles which thus appear like wrinkles proceed from hence, that they are the places where the tooth, while growing, is from time to time protruded or thrust out from the gum.

In the teeth shed by children, and likewise in those of many young animals, I have observed that the ends of their roots are entirely open or hollow ; and in like manner I imagine that the roots of the molar teeth or grinders which I have been just describing, are at first formed in the same manner, but that in process of time they become ossified or converted into a boney substance, of a spongy nature, through which many vessels pass, conveying blood, and nutritive juices into the cavity of the tooth, and I also conceive that this cavity is filled with nerves and vessels spreading themselves into many branches, that every one of the boney tubuli is thereby increased during the time of its growth, and afterwards, (while the tooth continues sound) nourished and supported. I also conjecture that these small vessels thus nourishing and supporting the boney tubuli do not end at the surface of the tooth (I mean, in that part of it which is within the gum) but that the aliment or nutritive substance has a continued course through these vessels, and that the ends of the boney tubuli are again converted into soft or pliable vessels, spreading through the gum, and that those vessels are what principally keep the tooth fixed in its place.

The first formation, and subsequent support or nourishment of the

tooth being as before described, we may easily conceive that the boney tubuli, (being of a solid nature, and incapable of dilatation or spreading) may happen to be obstructed by some gross or concreted matter, and then the small vessels contained within the cavity of the tooth must immediately by such obstruction in the circulation of their juices be distended. This distention or swelling will necessarily excite great pain, for all the vessels contained in the tooth will press closely on each other, forasmuch as they cannot swell or spread themselves as other vessels can, which are not confined within the solid substance of a bone. Again, supposing these boney tubuli to be obstructed, and the obstruction not removed, we may from thence gather the reason why our teeth partially decay, sometimes on the sides, and sometimes at the tops, the rest of the teeth remaining sound for several years after.

In order to shew the proportion which the size or thickness of the tooth bears to its component parts before described, I placed a very small piece of this tooth before the microscope, and delivered that microscope to the limner, directing him to draw an exact representation of what he saw, (but without acquainting him what that object was). And here I must observe, that in this tooth the tubuli appeared to me much larger than I had before observed in any animal, or in the elephant's tooth.

In Plate V. at *fig. 2*, K L M N, is represented * an exceeding small particle, or piece of a human tooth, of that sort called the molar teeth, or grinders, as seen through the microscope. The reason why in this figure some of the tubuli there pictured appear of a darker shade than the rest, is only this, that in that place where they seem darker there were more of the tubuli lying one

* The author having just below informed us, that 120 of the boney tubuli make only the forty-fifth part of an inch, we may, by counting the tubuli represented in this figure, judge the natural size of the fragment, or piece of tooth here magnified, and it will be found to be about the fortieth part of an inch in length and the fiftieth part of an inch in breadth, or of the size shewn at X.

behind the other, owing to the piece of tooth being thicker in that part, for this small fragment was split off, and not cut from the tooth.

The breadth of this tooth was almost two fifth parts of an inch, and from the best computation I could make, I judged that within the forty-fifth part of an inch, I saw an hundred and twenty of the tubuli, which amounts, in the space of one inch in length, to five thousand four hundred: now supposing this molar tooth, or grinder, before described, to be of a round figure, the diameter of it would be 2150 times the thickness of one of the tubuli of which the same is composed, and when this number is multiplied into itself, the product is 4,822,500. In a word, the proportion of one of the boney tubuli to the size of such a tooth, is as one to 4,822,500

Notwithstanding I had now obtained a very satisfactory insight into the formation of the human tooth, I was not yet content, but became desirous to examine into the nature of the substance, or vessels contained in the cavity, and for this purpose, I procured some of the fore teeth, and the jaw-bone of an ox, which were taken out and brought to me immediately after the animal had been killed; several of these fore-teeth, and some of the grinders, I broke, or split open, and with great admiration observed, that those vessels, which, passing through small apertures in the lower part of the tooth, filled all the cavity within, consisted of such an inconceivable number of blood-vessels, and other vessels, as to surpass all imagination: indeed, many of them I observed to be as small and slender as the tubuli themselves, of which the tooth was formed; and among them were small blood-vessels branching out into still smaller ones, many of them entirely colourless; therefore, I thought it probable that there might be still smaller vessels entirely undiscernible by our sight.

All these vessels were inclosed in a membrane, or coat, which was easily to be separated from the bone, and, having kept some

of these teeth by me four or five days before I broke them open, (in which time all the internal moisture was evaporated), I observed in some places within the tooth, a bloody substance which had penetrated into the boney tubuli, giving some of them a reddish colour.

It is my custom, every morning, to rub my teeth with salt, and afterwards to wash my mouth, and after eating I always clean my large teeth with a tooth-pick, and sometimes rub them very hard with a cloth. By these means, my teeth are so clean and white, that few persons of my age * can shew so good a set, nor do my gums ever bleed, although I rub them hard with salt; and yet I cannot keep my teeth so clean, but that upon examining them with a magnifying glass, I have observed a sort of white substance collected between them, in consistence like a mixture of flour and water. In reflecting on this substance, I thought it probable, (though I could not observe any motion in it,) that it might contain some living creatures. Having therefore mixed it with rain water, which I knew was perfectly pure, I found, to my great surprise, that it contained many very small animalcules, the motions of which were very pleasing to behold. The largest sort of them is represented in Plate V. *fig.* 3, at A, and these had the greatest, and the quickest motion, leaping about in the fluid, like the fish called a Jack; the number of these was very small. The second sort are represented at B, these often had a kind of whirling motion, and sometimes moved in the direction represented by the dotted line C D, these were more in number. Of the third sort, I could not well ascertain the figure, for sometimes they seemed roundish but oblong, and sometimes perfectly round. These were so small, that they did not appear larger than represented at E. The motion of these little creatures, one among another, may be imagined like that of a great number of gnats, or flies sporting in the air. From the appearance of these, to me, I

* Mr. Leeuwenhoek, at the time of writing this, was upwards of fifty years of age.

judged that I saw some thousands of them in a portion of liquid, no larger than a grain of sand, and this liquid consisted of eight parts water, and one part only of the before-mentioned substance taken from the teeth.

With the point of a needle, I took some of the same kind of substance from the teeth of two ladies, who I knew were very punctual in cleaning them every day, and therein I observed as many of these animalcules as I have just mentioned. I also saw the same in the white substance taken from the teeth of a boy about eight years old; and upon examining in like manner, the same substance taken from the teeth of an old gentleman, who was very careless about keeping them clean, I found an incredible number of living animalcules, swimming about more rapidly than any I had before seen, and in such numbers, that the water which contained them, (though but a small portion of the matter taken from the teeth was mixed in it,) seemed to be alive.

Some time after making the preceding observations, I received from Sir Hans Sloane, a packet, containing three small maggots, two of which were dead, and the third alive, with a letter, informing me that they were found in a person's decayed tooth, from whence they had been expelled by fumigation. Upon examining these, I had no doubt that they were of the sort found in cheese, and upon comparing them with some living ones which I procured from a cheesemonger, I found them to correspond exactly in make and shape. These maggots are the offspring of a small fly, which is frequently seen in cheesemongers' shops, and lays its eggs in the cheese, where the little maggots produced from them find nourishment, and are in time converted into flies.

The maggots sent me by the cheesemonger, I kept in a glass tube, and supplied them with food, and in a short time they were converted into flies, which laid eggs, and these again produced maggots of the same kind as the former. The living maggot

which I received from Sir Hans Sloane I kept by itself, and it was also converted into a fly of the same species.

These maggots when first hatched from the egg, are no bigger than a grain of sand, but afterwards grow to about four times that size; they have two small teeth by which they are enabled to gnaw their way into the cheese; and as their skin is very firm and hard they are not easily crushed or destroyed. Now, it is easy to conceive, that the person in whose tooth the maggots first mentioned were found, might have been eating of such old cheese, and that the maggots, or the eggs producing them, might have been lodged uninjured in the cavity of the tooth, where, when they began to gnaw, they must cause great pain; and we may also easily imagine that by the fumigation they might have been driven out of the part.



ON COFFEE.

IN my inquiries into the nature of several kinds of seeds, I examined, among others, those which are called Coffee Beans, which are much in use in this country, for preparing the well known drink of that name.

I was first desirous to know in what part of these seeds the young plant was placed, and for this purpose I procured some entire coffee beans, inclosed in their original husk or shell.

In Plate V. *fig.* 4, E, F is represented this nut, husk, or shell, in which are two of these coffee beans, divided by a membrane, or partition: for, that which at first sight appears as a single seed, does in fact consist of two distinct beans or seeds, lying in regular order beside each other, just as we observe two kernels in an almond, a filbert, or an apricot.

In *fig.* 5, G H, is shewn the nut or shell, opened on one side, shewing how the two beans lie with their flat sides next each other; G, is that part which was joined to the plant, and from whence the seed derived its nourishment, and H, is the end where the young plant is formed in the seed: *fig.* 6, I K, is a coffee-bean lying with its flat side upwards.

I cut a slice from one of these beans, at the end marked I, and caused a figure of it to be drawn, somewhat magnified, only to shew the place where the young plant lies.

Fig. 7, L M N, is this slice, and at O is to be seen the part of the

bean where the young plant is formed ; and here that part which would have grown up into a stalk or stem, is cut transversely.

I have also laid coffee beans for some time in water, in order more easily to take out the young plant, and to give a drawing of it from the microscope. This young plant, so magnified, is shewn in Plate V. *fig.* 8, P Q R S T V. At Q R S T V are three compleatly formed leaves, and I could see the vessels and globules whereof they consisted very distinctly in some of them, especially where the leaves did not lie two or three together. A few of these globules, composing the leaf, are represented in this figure, at letter T. That part where the root and stem would shoot forth is shewn at P Q V.

After this young beginning of the plant had stood some months before the microscope, I perceived that the leaves were covered with a sort of mouldiness. This appearance usually begins by a kind of stalk ; from whence a globule proceeds, and out of that many more, exhibiting together the likeness of foliage, but the mouldiness I am now speaking of, had a very different appearance, being much more in the shape of flowers, as is shewn in *fig.* 8, at a a a a. But I have often seen this mouldiness, even on the dead bodies or parts of the bodies of insects, and also on the shell of a silk-worm's egg.

Some of these beans I placed in a proper chymical vessel over the fire, and observed, that in the roasting, or burning them, a great great quantity of oily substance. and also of watery moisture was expelled. The roasted beans I broke into small pieces, and after infusing them in clear rain water, I suffered the water to evaporate, after pouring it off from the grosser parts of the coffee, and then I discovered a great number of oblong saline particles of different sizes, (but most of them exceedingly minute) all of them with sharp points at the ends, and thick in the middle.

Afterwards, I took some of the coffee beans in the same state they

are imported to us, and upon squeezing, or pressing them with great force, a larger quantity of the oil was expressed than could be imagined, and I observed that this oil was very clear and thin.

I also cut coffee beans into very small fragments, or pieces, in every direction, and I always found them to be of a very open and spongy texture: for, whereas, almost all feeds consist of a farinaceous, or mealy substance, (except in that part where the young plant is contained) this feed, on the contrary, is formed of nothing but fibres, branching or spreading one among another, and the cavities between them, in many places, filled with oil; for when I cut off very small pieces from the bean, I could plainly perceive the oil, and take it out from the part where it lay.

From the middle of a bean, I cut a very small slice, and placed it before the microscope, in order to shew the open and spongy texture of this feed; and in Plate V. *fig. 9*, A B C D, is represented this particle, or piece of bean when magnified, the natural size of which was no larger than might be covered by two grains of sand. The parts which in this figure appear closed up, and some of them to consist of globules, were filled with oil. When a coffee bean is thus cut into small pieces, and the pieces pressed between the fingers, or squeezed between any hard substances, the fingers, or whatever is used in such pressure, will be much stained with oil; (that is to say, in proportion to the force applied) and I will venture to say, that by a single operation of this kind, more than one thousand little drops of oil will be expressed: it is here to be noted, that the oily particles formed in the coffee bean are not perfectly of a round figure, but in many places they lie together in irregular shapes.

This formation of the coffee bean being considered, we need

no longer wonder, that they cannot be reduced into powder until they have been roasted, or burnt, for, in the roasting, much of the oil is driven off and consumed by the fire, and the branchey, or fibrous particles become weaker or more brittle, and the more they are burnt, or roasted, the more easily they can be pounded in a mortar.

As to myself, who am accustomed to take this kind of drink every morning for breakfast, I do not suffer the coffee beans to be much burnt, and I cause them to be pounded, or reduced into such small particles, that they will pass through a filken sieve, and until they feel between the fingers as fine and smooth as flour. A proper quantity of the coffee thus prepared, being put into a coffee-pot, I pour on it boiling rain water, and then set it again on the fire, but not to boil, and after letting it stand for a short time to settle, this is the coffee I make use of.

This is not, indeed, a very profitable way of making coffee, though much more grateful and pleasant to the palate, except to those who like the burnt flavour. For, when the coffee beans are violently roasted, they can more easily be pounded to powder and passed through a sieve, and the liquor clarifies sooner; and also, by reason of the burning, the bitter taste spreads farther, and produces more of the liquor, especially if the coffee be boiled in the water.

But, if we judge, that the oil and salts which are found in coffee, are the parts wherein its virtue consists, and from which we are to expect benefit to our health, we shall prefer that coffee which is not over roasted, to that which is more burnt, for, in the coffee which I drink, I always observe a great quantity of oily particles swimming on the surface, which would not be found there, if the coffee were more roasted, for in that case the oily particles are more driven off by the force of the fire.

Many persons say, that coffee is not wholesome, unless it is made bright and clear before it be drank; but this, I think, is of no consequence, because I am well convinced that the particles of coffee, (excepting the oil and salts, which I have before mentioned to be contained in it,) are of so hard and inflexible a nature, that they never can be introduced into the system of our bodies.

I have oftentimes endeavoured to bring coffee beans to a state of growth and vegetation, but herein I never could succeed: whether this was, because they had been kept too long, or whether, that at the place of their growth, they had been over dried, to facilitate their exportation to distant countries, whereby the juices which should have nourished the young plant were dried away, I cannot pretend to say.

I have several times placed coffee beans in a clean glass under water, without finding any alteration in the colour of them or of the water; but when they were so placed that part of them was above the surface of the water, then both the coffee-beans and the water became of a grass green colour.

I formerly thought that these coffee beans were produced by sowing them annually in the manner of our pease and beans in Europe, but I have been lately informed by a Gentleman who has travelled in the East, that they are the seed or fruit of a tree which grows to about the size of our lime trees.*

* The coffee-tree is a native of Arabia, from whence in the last and present centuries it has been cultivated both in the East and West Indies, but the Mocha coffee is still in the greatest estimation.



ON VINEGAR.

I HAVE observed, that on exposing a small quantity of white wine Vinegar to the air for a few hours, a vast number of corpuscles, or small solid substances appear in it, which I take on myself to name the salts of Vinegar. Some of these are represented in Plate V. *fig.* 10; those at A appeared to terminate in a sharp point at each end, having in the middle a dark spot; others were glittering like crystals, as at B, and these were most in number: others of these corpuscles were of an oblong figure, and of a dark colour, with a lucid spot in the middle, as at C; and some few of an oval form with an oval bright spot in the middle, as at D. Among the figures A, B, D, I was convinced that I saw several with a cavity or hollow in them, which gave them the appearance of being half dark coloured, and half transparent. Others of these salts or crystals laid one on another in clusters, as at E; and lastly, some there were with points at one end only, like half crystals, as at F. It is not easy to describe the extreme minuteness of these corpuscles, and some of them were indeed, so small that they almost escaped the view of the microscope.

All these particles, which I name the salt of vinegar, I conclude to be those parts of it which excite on the tongue that taste or sense named acid. And, although they appeared to me, through the microscope, of the shapes and sizes I have mentioned, yet I concluded that they were all composed of still smaller particles, of the same shape, in like manner as I have often in our common sea-water, or in water wherein common salt is dissolved, when placed before a microscope, seen many particles most exactly quadrilateral, or four-square, but so minute that millions of

them were not equal to a grain of sand; and these, while I contemplated them, would increase in size still preserving their exact square figure. In like manner I conclude, that there are none of these sharp pointed salts which I observe in vinegar, but are composed of numbers of smaller particles of similar shape.

Having kept in my parlour for about two months, a glass, two fingers broad, with a small quantity of vinegar in it, exposed to the air, I observed, at the end of that time, numbers of saline particles swimming on the surface, and, upon more narrowly examining them, I plainly discerned, what I had not so clearly seen before, that these saline particles had a kind of cavity in them, as easily to be seen, as if, with the naked eye we were to look into a small boat or a ship, and which, the longer the vinegar was suffered to stand, grew larger: some of these, with the cavity in front, are represented at G, and at H some of the same seen sideways. I also caused a drawing to be made of a living eel, of that species which is often found in vinegar, whereof the number I saw in this liquor was very great; this is shewn at L M; and at N O, another eel dead, which I killed, on purpose that the limner might take it's figure more accurately. These eels (which are invisible to the naked eye) I caused to be drawn, that by comparing them with the before-mentioned saline particles, the extreme minuteness of those salts might be the better conceived, and it should be understood, that by far the greater part of these salts could not be discovered by the common microscope, which made the eels visible. I am also desirous to convince those of their error, who imagine, that the acid taste of vinegar arises from the pungency, or sharp, sensation, which these eels are supposed to excite on our tongues, by their pointed tails; for, were this the case, many sorts of vinegar would be tasteless, because none of the eels are to be found in them; and in winter time, vinegar would become vapid, or lose it's sourness, because these minute eels are killed by cold or frost.

I was desirous to observe the effect of crabs' eyes being infused in vinegar, it being said that they absorb or take away its sourness, and I concluded that this must be performed by the acute salts before mentioned being altered in figure, or rendered more soft or flexible, so as to lose their pungency on the tongue. I took therefore, some new glasses, and after mixing in them vinegar with crabs' eyes broken in small pieces, I found, that the long pointed salts I have before described, were altered to a kind of oblong quadrilateral figure rising in the middle in form of a pyramid, similar to a diamond when polished; these are represented in *fig. 10*, at P, others were exactly square, as at Q, and others of the shape represented at R. But it is to be noted, that these particles bore no proportion in point of size to the saline particles in common vinegar, for these last were drawn from much deeper magnifiers, without the help of which, I could not have discovered their shapes. And, what I particularly wondered at was, that these saline particles were almost all of the same size, which I never observed in any other species of salts. After the effervescence produced by the mixture of the vinegar and crabs' eyes was subsided, I drank about a third part of a thimble full of the vinegar, and found that it had no acid taste, but a bitterness, so disgusting, as almost to occasion a nausea or sickness.

I have also pounded white chalk and mixed it with vinegar, and I found that it produced the same effervescence as the crabs' eyes, and the same change of figure in the saline particles, and that it also took away all the acid taste of the vinegar.



OF THE SCORPION.

THE Directors of the East India Company in Delft, having sent to me a living Indian Scorpion, I put it into a long and wide glass tube, stopped at the ends with cork, though not quite close; and I presumed that, on account of the coldness of the glass, the Scorpion would place itself on the cork, and so be preserved longer alive: and I occasionally put it into a thinner glass tube, in order, as far as I was able, to examine it by the microscope.

I first made my observations on its legs, the fifth joint of which, from the body, being very transparent, I there plainly perceived the blood running in an artery towards the extremity of the foot; which artery, I judged to be the size of an hair of ones head and close beside it, the blood was returning in a vein of the same thickness. These two vessels I deemed to be the principal blood-vessels in that limb, and, though I was well assured, that there were many small branches through which the blood was conveyed out of the artery into the vein, and thus the circulation was completed, yet I could not get a sight of those minute vessels.

The blood of this creature not being of a red colour, it may be ranked among those animals, which the antients named exsangues, or bloodless.

I saw that this Scorpion had two black eyes; placed, not at the extremity of the head, as we observe in many small animals, by which they discover objects on both sides of them; but these two eyes stood about the eighth part of an inch towards the back

part of its head, and seemed designed for the view of objects upwards. And I discovered, on each side of the head, three other eyes, only an eighth part the size of the before mentioned ones, placed in regular order beside each other, so that these creatures are provided with eight eyes; and, as the two eyes on the top of the head are only fitted to look upwards, so, these eyes placed on the sides are calculated to supply the defect of the former ones. And herein we see, with how much perfection and provident foresight, every creature, however disgusting it may be to us, is formed by Nature; and that none of such creatures have ever proceeded from corruption, as some men have imagined, but have been produced by their like ever since the Creation.

I put two living flies into the glass with this Scorpion, in order to see whether it would seize them as its prey; but they appeared not at all frightened at the Scorpion, even sitting upon its body, and the Scorpion was equally indifferent, and did not move itself on account of the flies. I afterwards put a small lizard, newt or eel; and likewise a spider and a fly at the same time into the glass with the Scorpion; but it appeared equally indifferent to them all; and after I had kept it by me almost three months, in which time it had not taken any food, it died.

As soon as I perceived that the Scorpion was dead, I took a pair of small forceps, and laid hold on that part in which I was persuaded the poison was deposited, and brought the sting before the microscope; then, by a little compression of the forceps, I caused the poisonous matter to issue forth, which might be thought to be emitted at the very extremity of the sting, but upon examining the sting by the microscope, I found that on each side of it, near the point, was a small aperture.

I have caused a drawing to be made of this Scorpion, in order to explain the nature of its sting.

Plate V. *fig.* 11, represents the Scorpion itself, and at A, is the sting, which the animal, whether in motion or at rest, always

carries with its tail bent, or turned inwards, in order, most probably, to preserve the sting from any injury it might sustain by the blunting of the point, or otherwise.

Fig. 12, F G H I, represents the sting, as seen through the microscope, and, between the letters G and H, may be seen the aperture which the sting has, on one side; and *fig. 13*, K L M N, represents the other side of the sting where the same aperture is to be observed between the letters L M.

It must here be noted, that the prominent part which is seen in *figs. 12* and *13*, at letter X, is not to be taken for a second sting, for in my opinion it serves only as a base or support, to be fixed on the skin, in order that by its help, the sting may be thrust in with greater force.

Upon reflecting frequently on the make of this sting, I considered with myself, that, if the above mentioned aperture had been at the very extremity, the sting could not so easily have been made to pierce the skin: I also thought, that the Scorpion has not power to expel the poison, but that when the sting enters the flesh, then the sides of the oblong cavity in it (which is seen in the *figs. 12* and *13*, between the letters G H and L M) are, by the pressure on the sting in its entrance (in regard the inner parts of this cavity are of a soft and yielding nature) forced inwards, and by that means the poison within the sting is driven out. Now, if the Scorpion had power to eject its venom, I imagine that it would not strike at any object whatever with its sting, without at the same time emitting some of the venom; but as this is not observed to be the case, we must conclude, that the poison is kept within the sting, until, by the force applied in piercing the skin or flesh, the poison is driven out, and there it will exert its full force upon the juices of the wounded part.

The liquid matter, or poison which I before mentioned to have extracted from the sting by pressure (though it was in a very small quantity) I put into a clean glass, which I prepared on

purpose, in order, if possible, to discover the saline particles contained in it, which alone, as it seems probable, do render this liquid poisonous in so great a degree; but, with all my attention, I could not perceive any thing in it particularly worthy of noting.

This liquid, being in a very small quantity, and also being spread very thin, in a short time, all the moisture of it was evaporated, leaving a kind of thick gummy matter, mixed with various different particles, to which I could not assign any particular figure. Hereupon, I, without loss of time, made a puncture on my finger with a needle, and applied a small portion of the blood which issued from the part, to this poisonous substance, in order to see, whether the blood would undergo any alteration by the mixture. But, nothing of that kind appeared, for I could not discern any difference between the blood which was placed on the poison, and that which lay near it.

The next morning, I dissected the tail of this Scorpion, and, from each joint, I took out two fleshy muscles, of a very white colour, each of which was composed of a great number of very small oblong particles, terminating at the extremity of the muscle where it grew smaller, thus forming the tendon: on one of these muscles was a kind of vessel, shaped in the middle like a bladder, and this, I concluded, was destined to convey the poison to the extremity of the tail. These fleshy muscles were furnished with annular parts, or rings, serving to extend and contract the muscle.

Those eyes which were situated on the upper part of the head, I placed before the microscope, whereby I saw how perfectly the tunica cornea, or horny coat of the eye was formed; for through it I could see all the surrounding objects (though wonderfully diminished) so distinctly, that I could not contemplate the spectacle without admiration; but this pleasing sight was not of long continuance, for the tunica cornea soon dried and shrivelled up.

Upon opening the belly, I could not form any judgment of the intestines, by reason that they had begun to decay, except that I

found twelve eggs, each about the size of a grain of millet, of a yellow colour, and in shape not unlike a lemon.

In the fore part of the head, and just in front of the mouth, I observed two teeth, each fixed on a short joint, and they are used, as I imagine, by the Scorpion, to grind its food, before it is taken into the mouth. These I separated from the head, and found each to consist of a three-fold tooth, one of which was so made, as to fit exactly the cavity between the two opposite ones. And, to shew the strength of these teeth, I caused a drawing to be made of one of them. *Fig. 14, O P Q R*, is this tooth, or more properly this three fold tooth, and on it, at *P*, are to be seen some hairs; the legs of this creature are also covered with hairs.

I also placed before the microscope one of the claws, which are like those of crabs or lobsters, and in *fig. 11*, are to be seen at *C* or *D*. And I caused a drawing of this claw to be made, in order to shew the curious formation of it. *Fig. 15, S T*, is the claw, magnified, and on it are plainly to be seen a great number of teeth or notches, like those of a saw, some of them larger than others, and which saw-like teeth, I doubt not are so formed for enabling the Scorpion firmly to hold such small living creatures as it catches for its prey.

Seeing now, the wonderful make of this animal, though to us it is so detestible, and indeed so noxious; and, considering the perfect wisdom requisite for the contrivance of its several parts, we have surely ten thousand times more reason to believe that its origin is derived from those which were created at the Beginning, than to adhere to the chimæras and errors of the ancients, some of whom have transmitted to us in their writings, the notion, that Scorpions are not produced by generation, but from the great heat of the sun; others, that they are bred from putrefaction in the bodies of crocodiles; and others again, that they are generated in rotten wood, and such like fictions.

ADDITION, BY THE TRANSLATOR.

It may not be unacceptable to the Reader, to subjoin a quotation from Dr. Mead's celebrated Essay on Poisons, and the rather, as the sentiments of our Author, in regard to the nature of the Scorpion's poison, are exactly similar to those of the Doctor's, when treating of that emitted from the Viper's fangs; which animal, being much larger than the Scorpion, might afford Dr. Mead a better opportunity of investigating the nature of this substance, than Mr. Leeuwenhoek could have, in the very small quantity which he collected from the Scorpion's sting: and, as we see that the operations of Nature are performed with the greatest uniformity in cases which are analogous, it may fairly be concluded, that what Dr. Mead has said, respecting the Viper's venom, may be applied to that of the Scorpion, and of more minute noxious animals.

Dr. Mead expresses himself on this subject, in the following words:

' This venomous juice itself is of so inconsiderable a quantity, that it is no more than one good drop that does the execution. And for this reason, authors have contented themselves with trials of the bite upon several animals, never essaying to examine the texture and make of the liquor itself: for which purpose, I have oftentimes, by holding a Viper advantageously, and enraging it till it struck out its teeth, made it bite upon somewhat solid, so as to void its poison; which, carefully putting upon a glass plate, I have with a microscope, as nicely as I could, viewed its parts and composition.

' Upon the first sight, I could discover nothing, but a parcel of small salts nimbly floating in the liquor; but in a very short time, the appearance was changed, and these saline particles were now shot out, as it were, into crystals of an incredible tenuity and sharpness, with something like knots here and there, from which they seemed to proceed: so that the whole texture did in a manner represent a spider's web, though infinitely finer, and more minute; and yet withal, so rigid where these pellucid spicula, or darts, that they remained unaltered upon my glass for several months.*

' I have tried several ways to find out, if I could, under what tribe of salts these crystals are to be ranged, and to discover what alterations they make in

* A representation of this, taken from Dr. Mead's work, is given in Plate V. fig. 16.

the blood : and, not without some difficulty, by reason of the minute quantity of the liquor, and the hazard of experiments of this kind, some curious friends, and myself together, made the following observations :

About half an ounce of human blood received into a warm glass, in which were five or six grains of the viperine poison newly ejected, was not visibly altered either in colour or consistence : it then was, and remained undistinguishable from the same blood, taken into another glass in which was no poison at all.

These portions of blood were severally mixed with acids and alkalis : the empoisoned blood was, after such mixtures, of the same colour and consistence as the other.

Spirit of nitre, spirit of salt, and juice of lemons, severally poured upon the sanies itself, produced neither fermentation, nor any change of colour.

Salt of tartar run per deliquium, and the simple spirit of hartshorn, dropped upon the venom, neither altered its colour, nor raised any ebullition.

Syrup of violets mixed with the poison did not change its colour either to red or green.

The tincture of heliotropium, that is, blue paper, was not altered by the sanies ejected upon it ; and this, drying, still retained its yellowish colour.

We caused several animals, dogs, cats and pigeons, to be bit by an enraged Viper ; which generally died, some in a longer, others in a shorter space of time. But we constantly observed, that they all, immediately upon the bite, shewed with signs of acute pain, marks of their life being affected, by sickness, faintings, convulsions, &c.

The head of a large Viper lay three hours after it was cut off ; it was perfectly flaccid and without motion. A pigeon, wounded upon the breast with the fangs of this head, was presently convulsed, &c. as from the bite of the animal, and died in seven hours.

We contrived a sharp steel needle to be made, crooked, in shape not unlike to the Viper's tooth, with a sulcus or hollow on the convex part, not far from the point : into this, we put a drop of the venom, and with it wounded the nose of a young dog. It produced the usual disorders of vomiting, purging, &c. but in a less degree, and the dog recovered. It was remarkable, that upon making the wound the dog cried but little, till the poison came into it ; but then he howled, &c. in the same manner as if bit by the viper itself. But a pigeon pricked in the fleshy part of the breast, by the same poisoned needle, suffered as from the bite, and died in about eight hours.

' We resolved to end our poison-inquiries by tasting the venomous liquor.
 ' Accordingly, having diluted a quantity of it with a very little warm water,
 ' several of us ventured to put some of it upon the tip of our tongues. We all
 ' agreed, that it tasted very sharp and fiery, as if the tongue had been struck
 ' through with something scalding or burning. This sensation went not off in
 ' two or three hours, and one gentleman, who would not be satisfied without
 ' trying a large drop undiluted, found his tongue swelled, with a little inflam-
 ' mation, and the soreness lasted two days; but neither his, nor our boldness,
 ' was attended with any ill consequence.

' This is no objection to the hurtful quality of this juice: for, as some chy-
 ' mical liquors ferment with others of a certain kind only, so these poisonous
 ' salts may affect one fluid of the body, and not another; it is sufficient to the
 ' present purpose to say, that the saline spicula are broken and dissolved in the
 ' mouth by the clammy salival humour: and if any of them should pass thence
 ' into the stomach and intestines, the balsam of the bile will be an antidote
 ' there, powerful enough to overcome their force.

' These experiments upon the Viper poison and the blood, are a sufficient
 ' confirmation, that the nervous liquor only is affected by this venom; and at
 ' the same time afford a convincing proof, how much those scanty principles of
 ' our chymists, acid and alkali, fall short in explaining the actions of natural
 ' bodies; since neither of these salts could in any way be found to affect the
 ' viperine venom.'

Mechanical Account of Poisons, p. 14, & seq. Ed. 1747.

The Doctor's Essay on the Nervous Fluid and the manner in which it is
 affected by animal poisons, is too long to insert in this place, but the Reader
 will find it in the Introduction to the work from which the preceding passage is
 taken; that is to say, in the later editions, for it is not to be found in the first,
 printed 1702.



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Of the Oak gall, or Gall-nut; that it is not a fruit, but an excrescence produced on the leaves of the oak, by means of an insect; the manner of its formation particularly described. A similar excrescence produced in like manner on the Thistle.*

WHILE I was employed in the summer season, to collect acorns from the oak, in order to examine the beginning plant in that feed, I saw with surprize, that the gall-nuts were produced upon the leaves of the trees. This seemed the more extraordinary, because I had supposed that they were the fruit of the tree, but now I found that they were occasionally, or accidentally produced on the leaves of the oak. I was convinced of this, partly, because I saw but a few leaves here and there with gall-nuts on them, (in some of which I found four, five, and even six galls) and in others I could not find a single one; and in the next place, because I saw, that these galls were formed upon the large fibres, or vessels in the leaves, which were burst or broken, in the places where the galls were formed; so that I concluded that some insect had wounded or gnawed those vessels, and that the juices of the tree, flowing out of the wounded part, had extended themselves in globules and vessels, and thus, at length caused the formation of the gall-nut.

* This is a literal translation of the Dutch word *Galnoot*, used by the Author; in the Latin translation it is *Galla*, which Ainsworth renders 'a fruit called gall, or oak-apple;' but this is a mistake, for the oak-apple is not the gall, nor is it formed on the leaves of the tree, but at the ends of the small twigs; and it is produced, not by a single insect, but by a great number collected together, and those of a different species from the insect found in the gall-nut.

On my return home, I examined these gall-nuts more accurately, and found that each of them had a cavity in the middle, wherein lay a living white worm, which had very little motion: it was thick, in proportion to its length, and lay bent in a circular form, the body of it consisting of thirteen or fourteen rings, as we see silk-worms and caterpillars, and these covered with pointed hairs.

It seemed to me worthy of observation, that, from this time, I observed these worms, or maggots, continue alive to the end of December; and that, in gall-nuts which I had gathered in the summer, and which were so dried, that I thought they were shrunk to half their former size; whereupon I concluded that the worms, for want of sufficient nourishment, had not arrived at their full growth, so as to be changed into flies, and had only been supplied with food sufficient to keep them alive. But, when they had grown to be somewhat larger than a great pin's head, then I saw the eyes beginning to be formed, which were of a black colour.

After this, I went occasionally into the wood at the Hague, in order to pursue my speculations, and observed that these worms were changing into flies; for, I not only could see their eyes perfectly formed, but I also could discern plainly their horns and feet, and the hind part of their bodies. This insect then lay without any motion that I could perceive, with its feet, six in number, and its two horns lying in regular order close to its body, in like manner as we see in the aurelia of the silk worm, before it comes out of its shell, or covering, but in this animalcule I did not then observe any such case or covering; but only the shape of a small fly without wings, the hind part of its body of a round form and of a shining black colour, and which in a short time was provided with two larger and two smaller wings: and I afterwards found that these aurelias had a thin covering, which enclosed the body, but not the feet.

From these my observations, I concluded, that these animalcules

were thus produced, namely, by the before-mentioned kind of fly, laying its eggs on the leaves of the oak, where, when the young maggot is hatched, it bites or pierces the vessels of the leaf, so that the juices flow out, and are hardened into globules, spreading themselves, at the same time, in a circular form like vessels, and thus produce what is called the gall-nut, and which juices, while hardening, do inclose the maggot in the middle.

This newly-formed gall-nut supplies the animal with food, for it eats away the substance of the nut by little and little, round about itself, whence proceeds the cavity we find in the middle of these galls, and which cavity grows larger, as the animal increases in size. And it seems to me, that unless some of the large vessels in the leaves were injured or perforated by one of the maggots I have described, there could not be any gall-nut formed, for in every nut which I opened, I constantly found a maggot (though in an hundred such nuts, I found but two which contained more than one) and this, though one gall-nut was sixty times the size of another,

It is however to be noted, that the wounding or biting the large vessels in the leaves, does not constantly produce a gall-nut; for this is only formed, where a sufficient quantity of the juices issues from the opened vessels; to this also, the heat contributes much, by condensing or thickening the juice; and hereupon it is my opinion, that where these vessels are opened in the morning, galls will more easily be formed than when it happens in the evening; for I saw on those leaves on which were gall-nuts, and also on those where none were to be seen, the leaves and vessels much eaten into, and the vessels pierced through, and yet, not the least appearance of the formation of a nut on the place. Farther, I concluded, that many of these maggots get their sustenance from the leaves without piercing the large vessels, for in many places I saw the leaves eaten away and in holes.

In further prosecuting my inquiries on this subject, I found

that the best sort of gall-nuts which are used in this country, are brought from Aleppo. Hereupon I consulted Tavernier's Travels, to see what he says on this subject; and I found, that in his third book, when speaking of his journey to Aleppo, he says, 'the hills are covered with oaks bearing the gall-nut, and some of them, besides gall-nuts, also produce acorns.' But, after the preceeding observations, we are not to wonder, that the same oak will produce both galls and acorns, since nothing more is wanting for the production of a gall-nut, than such a fly as I have mentioned, from the eggs of which, worms shall proceed, which feed upon the leaves of the oak.

To satisfy myself more fully in this particular, I examined several of those gall-nuts which are imported to us, and are much used by dyers; and in some of them I found a dead fly, of the same shape with those found in the galls of this country, and in others, only a cavity in the middle, with a round hole reaching from that cavity to the surface of the nut, and in the cavity a kind of dust, which I imagined to have been the excrements of the worm while it was in the nut. And I found upon farther prosecuting my observations on the galls which I gathered from the trees here, that not only the maggot is able to gnaw the substance of the nut; but also, that the fly has power to perforate it, to open a passage for itself though I do not think that the fly uses the substance of the nut for food.

In others of these Aleppo galls, I saw no appearance of any living creature having been inclosed; the reason of which I concluded to be, first, the maggot in our gall-nut, even when of its perfect size, is very tender, and crushed with the least touch, and contains nothing in it, but a whitish fluid substance, so that if a maggot happens to die in the nut, whether from the juices being too acrid, or the nut too hard, in such case, the substance of the worm may so dry away, as to leave no traces behind it. In the next place, a maggot, when grown to a considerable size,

may pierce a large vessel in the leaf, and afterwards shift itself to another place, and out of the large vessel so wounded, a gall-nut may be produced without any maggot in it. The gall-nuts which are formed without any insects in them, are generally the heaviest, by reason that they have not any cavity made in their insides.

With regard to my preceding observations on this species of fly, I was the more confirmed in my opinion, upon recollection of what I have observed of the like kind in divers trees, and particularly the willow; on the leaves of which I have seen certain green tubercles or swellings, on opening which I have found animalcules within them, some of which were alive, and others dead; all which I doubted not were produced by maggots hatched from the eggs of the flies of the same species as those which I had found in such tumours or swellings. For it is with me an established principle, that no living animal, whether worm, fly, gnat, or mite, can be produced from the mere juice or leaf of any tree or plant, nor from corrupted or decayed substances.

I have caused a drawing to be made of these galls, as they grow or are produced on the leaves; and in Plate V. *fig. 17*, A B C D, is represented an oak leaf, with that side upwards, which, when on the tree is undermost; for I never saw any of these galls on the upper side of the leaf; the reason of which I take to be, that if the maggot was placed on the upper side, and exposed to the sun's heat but for a short time, it would, by reason of its smallness, be dried up and perish. On this leaf are seen two large galls, and two smaller ones, at the letters E, F, G, H.

Fig. 18, 18, exhibit a gall-nut cut in half, wherein, at N, N, appears the cavity, in which the maggot lay; some of these maggots, of different sizes, are shewn at I, K, L, M.

Fig. 19, shews one half of a gall-nut, with the fly in it, which has opened to itself a passage from the cavity as far as the surface of the nut, and at *fig. 20*, is the other half, exhibiting the cavity in

the center, formed by the maggot, and the perforation to the circumference made by the fly.

Fig. 21, is the fly bred in this gall-nut, whose body is not quite so large as represented in this figure, but the wings are of the same size as they appear here.

After these observations, in the month of January, I again went in search of gall-nuts, upon the leaves of the young oaks, and those which hung near the ground; and I found a great number of them, although the leaves were very much dried: in many of these galls I saw the perforation through which the fly had issued; in others of them I found living flies; and in others, living maggots.

Some of these galls I placed in my closet, and opened them at different intervals of time, and I always found either the maggot in them alive, or a hole, through which the fly had issued: ten of these I kept till the end of April, and upon opening them, I found them all perforated with holes, and the flies which had issued from them, lying dead.

While I am on this subject, I can not forbear to mention, that in the autumn there were brought to me a parcel of roundish substances, which were gathered from thistles, and therefore, called thistle-nuts. Many of our countrymen carry these nuts in their pockets, under a notion that while they wear them, they shall be free from the disorder called the piles, particularly if every year, they throw away the old nuts and procure fresh ones (which, it is said, do not grow in our province). And some say, that there is a maggot in these nuts, and that while it lives, the before mentioned virtue remains in the nut, but upon its dying the virtue is lost.

As soon as I saw these supposed nuts, I concluded that they were produced, as I might say, by accident; and that their virtue against the piles was a mere imagination. And upon examining the nuts, I found that there was not one of them which had not one,

two, three, four, and some as many as seven or eight cavities in it, each cavity containing a short, white aurelia, or chrysalis, formed of many joints like rings; these aurelias were almost all alive, and I judged them to have been produced from maggots, the offspring of some fly or such like insect, which had laid its egg on the thistle; and that those maggots having pierced the vessels of the thistle, while in the flourishing time of its growth, had occasioned a copious effusion of juices, by means of which a tumor or swelling had been formed upon the thistle, which had inclosed the maggot, and formed a solid substance round it. And upon further prosecuting this subject, to elucidate my own position that these nuts had been produced by means of maggots, I opened several of them at different times in the succeeding winter, preserving the aurelias; and at length, towards the end of the April following, they produced a species of black flies, different from any I had before seen, for the hind part of their bodies terminated in a point, forming a kind of sheath, wherein was contained a small sting.

I thought it would not be amiss, to exhibit to the view, the shape and make of these nuts, in order to shew the sizes of them and of the cavities they contain; and also how far, fancy and imagination will go with some people.

Plate V. *fig.* 22, 23, 24, represent three of these thistle-nuts dried, and of different sizes.

Fig. 25, is one of the same nuts, cut open on the side, where may be seen two cavities, one of them, at A, containing an aurelia.

Fig. 26, is the fly produced from this aurelia.

Fig. 27, is a thistle-nut cut across, shewing seven cavities, wherein the aurelia had lain.

END OF THE FIRST PART.



INTRODUCTION to the SECOND PART.

AS I have entitl'd this Translation, *The Discoveries of the Author* in many of the Works of *Nature*, (a term us'd by himself,) I shall take the liberty to lay before the Reader a few words, respecting the idea we ought to annex to that expression.

By the word *Nature*, here us'd, I understand that unseen power, whereby different parts of *Matter* are brought together, and, by their various combinations and modifications, produce those bodies or substances which we observe on this terraqueous globe. *Matter*, is that *Something*, of which bodies are compos'd, and I call it *Something*, because its primary or original particles are so minute, as to be entirely undiscernible by us; for it is not until they are combined or collected in larger portions, that they become objects of our senses. This is capable of demonstration many ways. For example, *Earth*, which, in itself, has little either of taste or smell, produces herbs, flowers, and fruits, possessing an endless variety of tastes and odours; and not only so, but of natures entirely different from each other, the same spot of earth which produces wholesome herbs for our tables, bringing forth also the most noxious plants, according to the quality of the seed or plant committed to it: And yet, we cannot trace these various tastes and odours, nor these wholesome and noxious properties, in plants, to any other original, than the same common parent, *Earth*, aided by such supplies as they receive from the other *elements. Herbs, taken into the stomachs of animals, are converted

* Water, it is well known, is essential to the growth of plants, neither will they vegetate without a supply of air, a fluid eight hundred times lighter than water; and, it is the opinion of Sir Isaac Newton, that light, which is beyond all conception more rare and subtile than air, does enter into the composition of bodies.

into the fleshy parts of their bodies, and even compose the solid substances of the bones and teeth : and all these vegetable and animal substances do, by putrefaction, return to the general mass of Matter from which they were first formed, and enter into the composition of new bodies. Again, water evaporates, or is carried up into the atmosphere, in particles so small as to be invisible to us ; and even mercury or quicksilver, the heaviest of all fluids, upon the application of a moderate degree of heat, flies off in vapour, and, unless confined by some solid body, such as a chemist's retort, wholly disappears. Arguing then, from these appearances, we must conclude, that the elementary or original particles of Matter, are not, as such, discoverable by us. And, as far as ocular examination can reach, Mr. Leeuwenhoek has given it as his opinion, that, were he able, by the help of glasses, to discern objects, millions of times smaller than those his microscopes discovered, he should still fail of tracing bodies to their original component particles.

Some Philosophers have spent much time, in arguing on the infinite divisibility of Matter, and in proposing strange * theories respecting its inherent properties. But herein, they seem to have exercised their wits, without much improving their understandings ; for surely, it is of no utility to propound questions, which cannot possibly be brought to the test of experiment. In opposition to these vain speculations, how wise, and, at the same time, how modest, are the words of Sir Isaac Newton : † “ It seems probable to me, that God in the Beginning, formed Matter, in solid, massy, hard, impenetrable, move-
“ able particles, of such sizes and figures, and with such other proper-
“ ties, and in such proportion to Space, as most conduced to the end for

* Such as that of supposing the cohesion of bodies to be caused by their particles being formed with little hooks ; and, that repulsion proceeds from other particles being made like hoops rolled up, and afterwards expanding themselves.

† Newton's Opticks, Qu. 31, near the end.

“ which he formed them ; and, that these primitive particles being
 “ Solids, are incomparably harder than any porous bodies compounded
 “ of them, even so very hard, as never to wear or break in pieces ;
 “ no ordinary power being able to divide, what God himself made one
 “ in the first Creation. While the particles continue entire, they may
 “ compose bodies of one and the same nature and texture in all ages ;
 “ but, should they wear away or break in pieces, the nature of things
 “ depending on them would be changed. Water and Earth, com-
 “ posed of old worn particles, and fragments of particles, would not
 “ be of the same nature and texture now, with water and earth com-
 “ posed of entire particles in the Beginning. And therefore, that
 “ Nature may be lasting, the changes of corporeal things are to be
 “ placed only in the various separations and new associations and mo-
 “ tions of these permanent particles ; compound bodies being apt to
 “ break, not in the midst of solid particles, but where those particles
 “ are laid together, and only touch in a few points.” This seems to
 be the *ne plus ultra*, or utmost extent of human sagacity, terminating
 in a conclusion, worthy of that great Philosopher and good Man. In
 conformity to which, I think we may say, that the particles of Matter
 are not infinitely, but indefinitely small, or, in other words, so
 minute as to be, singly, invisible to us, though collectively, they are
 the daily objects of our senses. It now remains to consider the pro-
 perties of Matter, or, the means by which its particles are brought
 into action.

The Honourable Mr. Boyle has written an Essay on this subject,
 wherein he refutes the error of the ancient heathen philosophers, and
 their followers among the moderns, the Schoolmen, who figured to
 themselves, an active, intelligent Being, which they called Nature ;
 subordinate indeed to the Deity, but yet, presiding over the mundane
 System, and directing its operations. He shews, in a variety of in-
 stances, that the supposition of such a Being, is insufficient to solve

the different phænomena in the system, and, that it detracts from the honour of the Author and Governor of the World : And he gives us his opinion on the subject, in these words : * “ Since the present is a philosophical enquiry only, we shall only, at present, consult the light of reason in the formation of the World, which might probably, be after the following manner. The great and wise Author of things, first forming the universal undistinguished Matter, put its several parts into various motions, by which they must needs be divided into innumerable particles of different bulks, figures, and situations; guiding and over-ruling the motions of those parts, by his wisdom and power, so as to dispose them into that beautiful and orderly frame we call the World ; some being so contrived, as to form feeds, or the seminal principles of Plants and Animals. Besides, he settled such laws or rules of local motion, amongst the parts of Matter, that, by his ordinary concurrence, the parts of the Universe once compleated, should continue the œconomy of the Universe, and propagate the species of living creatures.” And again, he says, “ If we suppose the universal laws of motion to be established, and that, by their conventions, the seminal principles of various things were contrived, by the local motion of Matter, skilfully guided at the Beginning, and that God’s ordinary and general concurrence, contributed to perfect the Universe, and continue it so, there is no need of any distinct powerful intelligent Being to assist him, as Nature is represented ; since the Phænomena which occur, will flow from the mere fabrick and constitution of the World.”

The learned Dr. Mead has a passage on this subject of Nature, when applied to animated bodies, which I the rather quote, as it contains a reproof to those visionary philosophers I have mentioned.

† “ Whereas the Word Nature, is made use of by Physicians, in

* Enquiry into the received notion of Nature.

† Mead on the Small Pox, Chap. II.

" the cure of all diseases, I will here, once for all, plainly declare my
 " sentiments of what we ought to understand by that word. That
 " there is something within us, which perceives, thinks, and reasons,
 " is manifest beyond contradiction: And yet, the nature of that
 " *something*, cannot be fully and perfectly comprehended in this life.
 " Wherefore I shall resign the disquisition of this point to those, who,
 " while they know too little of, and care less for, things falling under
 " their senses, take great pleasure in investigating those things which
 " human reason is incapable of conceiving. However, thus far the
 " soundest philosophers agree concerning it, that it is somewhat in-
 " corporeal. For, how can sluggish Matter, which is, of itself, void
 " of all motion, be the source and first cause of thought, the most
 " excellent of all motions? Wherefore, it is sufficiently evident,
 " that this first mover within us, is a spirit of some kind or other, en-
 " tirely different and separable from terrestrial matter, and yet, most
 " intimately united with our body."

" Moreover, to me, it seems probable, that this active principle, is
 " not of the same sort in all; that the Almighty Creator has en-
 " dowed man with one sort, and brutes with another; that the for-
 " mer so far partakes of a divine nature, as to be able to exist, and
 " think, after its separation from the body; but that the latter is of
 " such an inferior order, as to perish with the body."

" Now this matter, if I am not mistaken, stands thus: Such is the
 " composition of our fabric, that when any thing pernicious has got
 " footing within the body, the governing mind gives such an impulse
 " to those instruments of motion, the animal spirits, as to raise
 " those commotions in the blood and humours, which may relieve
 " the whole frame from the danger in which it is involved. And
 " this is done in so sudden a manner, that it should seem to be the
 " effect of instinct, rather than voluntary motion, though it be ef-
 " fected at the command of the active principle. And, indeed, those

“ very motions, which are commonly called natural and vital, as
 “ those of the heart, lungs, and intestines, which persevere through
 “ the whole course of life, even when the will cannot be concerned
 “ in them, as they have their beginning from the mind, so they are
 “ perpetually under its direction.”

Sir Isaac Newton, in that part of his works above quoted, expresses himself as follows: “ All material things seem to have been
 “ composed of the hard and solid particles above mentioned, variously
 “ associated in the first creation, by the counsel of an intelligent Agent.
 “ For, it became him who created them, to set them in order. And,
 “ if he did so, it is unphilosophical to seek for any other origin of the
 “ World, or to pretend, that it might arise out of a chaos, by the
 “ mere laws of Nature; though, being once formed, it may continue
 “ by those laws, for many ages. For, while Comets move in very
 “ eccentric orbits, in all manner of positions, blind Fate could never
 “ make all the Planets move one and the same way, in orbits concentric,
 “ some inconsiderable irregularities excepted, which may have
 “ arisen from the mutual actions of Comets and Planets upon one
 “ another, and which will be apt to increase, till this System wants
 “ a reformation. Such a wonderful uniformity in the Planetary
 “ System, must be allowed the effect of choice. And so must the
 “ uniformity in the bodies of animals, they having generally, a right
 “ and a left side, shaped alike, and, on either side of their bodies, two
 “ legs behind, and either two arms, or two legs, or two wings before
 “ upon their shoulders, and, between their shoulders, a neck running
 “ down into a back bone, and a head upon it; and, in the head,
 “ two ears, two eyes, a nose, a mouth, and a tongue, alike situated.
 “ Also, the first contrivance of those very artificial parts of animals,
 “ the eyes, ears, brain, muscles, heart, lungs, midriff, glands, larynx,
 “ hands, wings, swimming bladders, natural spectacles, and other
 “ organs of sense and motion, and the instinct of brutes and insects,

“can be the effect of nothing else, than the wisdom and skill of a
 “powerful ever living Agent, who, being in all places, is more able,
 “by his will, to move the bodies within his boundless uniform
 “*Sensorium, and thereby to form and reform the parts of the Uni-
 “verse, than we are, by our will, to move the parts of our own
 “bodies.”

I hope I may be permitted to add to the opinions of these great men, an observation, which, I think, must have occurred to them, though they have not particularly mentioned it, except Sir Isaac Newton, in the last lines of the passage I have quoted from him. The laws of motion which, according to Mr. Boyle, were established at the Beginning, and afterwards continued, by what he calls, “the ordinary concurrence of the Creator,” and which principles are styled by Sir Isaac Newton, “the laws of Nature,” cannot have any force without the same exertion of power to support them, by which they were at first created. Nor can the incorporeal mind or spirit, mentioned by Dr. Mead, preserve its activity without the continued influence of the Supreme Mind. For, the case is not analogous to what may be supposed of a workman, constructing a machine, which shall for a length of time continue in motion, without his intervention; nor to that of a master, giving directions to his servants to perform, what they afterwards accomplish of themselves. For, in the one instance, the machine, if its first mover be a weight, is kept going by the law of gravity, and, if a spring, by the power of elasticity, both which are entirely independent of the workman; and, in the other instance, the servant executes his master’s commands by virtue of the powers of self volition and action he possesses, independent of that master, though, for the time, he willingly applies those powers to the accomplishment of the task assigned to him. But, we cannot

* Sensorium, means the seat of consciousness, or perception in animated Beings; and, when applied to the Deity, his Omnipresence makes it to be every part of Space.

conceive any active principle to exist, in either Matter or Spirit, without the support of the first Cause; for this would be to suppose more than one active independent Existence, which Dr. Clarke has proved to be the greatest absurdity.* Upon the whole, when we investigate this subject as far as our faculties will extend, we cannot do otherwise than resolve all, that we call the operations of Nature, into the continual agency of the first Creator. And, though we are lost in the idea of such immense and incessant energy, we are equally so, in the contemplation of any other of the Divine Attributes, forasmuch as finite capacities cannot comprehend Infinity.

While we possess these sentiments, and keep the idea of Nature, and the Author of Nature, connected, (which it is not easy for a reflecting mind to separate) I cannot, for my part, but approve the † personifying figure, which I think more decorous than to name the Deity on every trivial occasion: and Mr. Leeuwenhoek seems to have been of this opinion, for he frequently uses the expression “*de voorlichtig Natuur*” i. e. provident Nature, but when the wonders he discovers excite his admiration, that admiration is always directed to the Creator.

* Clarke's Demonstration of the Being and Attributes of God.

† The Antients pictured Nature in a female form, to denote her fruitfulness; and, with many breasts, to typify the abundant provision made by her for her different productions.



** The Author's opinion and reasoning respecting the formation of that species of fuel which is called Peat†, and also with regard to the trees dug out of those places where Peat is found: from whence he takes occasion to propose and discuss a question, whether the Sea may not, in process of time, become more elevated in respect of the Land.*

I HAVE heard many persons deliver their sentiments, respecting the manner in which that substance called Peat was produced in this country of Holland. The general opinion is, that the place where this Peat is found was, in former ages, nothing but a wood, and that the falling leaves and smaller branches or twigs of the trees, collecting together on the earth, did in process of time, produce this substance, which is by us called Veen. It is also believed, that those trees, numbers of which are found among the Peat, formerly grew in the same place, and were all blown down by some violent tempest of wind

* In this Essay, the Author departs from his usual method of investigating the works of Nature by the microscope, and proceeds upon theory. It will be seen, however, that he does, in one instance, draw a very strong argument in support of his hypothesis, from microscopical examination.

† The words Peat, and Turf, are sometimes used promiscuously, though their true meaning is very different. Turf, properly so called, as denoting an article of fuel, is composed of the thick roots of grass, pared off the surface of the earth on commons, and dried in the sun. The bark of oak, after it has been used by the tanners, made up into square pieces or cakes, and dried, is sold in London for firing, under the name of Turf. But Peat, of which the author here treats, is found under the surface of the earth, sometimes to a considerable depth.

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from the North-West, and that for this reason, the roots of all the trees so dug up at this day do point towards the North-West.

These opinions I have often controverted: for how can it be imagined, that so great a quantity of Peat could be produced from trees standing together in a wood; inasmuch as Peat is in some places found collected to the thickness of ten or twelve feet, and sometimes more? Neither can it be conceived, how those large oak trees, which are now found, lying in the midst of the Peat, could ever have grown to their full size in such a soil, for, a common storm of wind would have been sufficient to blow them down.

Again, it is well known, that those trees which are found at a considerable depth in the Peat never have on them the small branches on the stem, nor any small ramifications on the roots, and all those small light branches of alders and willows which are found in Peat, are not (as far as I have ever known) firm or solid in their kinds, but very much decayed, the same as if they had been for several years exposed to the air, or had died and withered on the trees, or were almost rotten. These decayed portions of wood cannot, as I conceive, have grown in the places where they are now found, but must have been carried thither by some flood, or stream of water, and that they either floated on the water, or had lain exposed to the air for several years, and therefore may properly be denominated decayed wood; and I remember, that on handling some pieces of willow about the thickness of a finger, which I myself saw dug up, I found them as soft and flexible as a withered carrot.

Now, if those oak trees, which are found at a great depth in the Peat, had originally grown in the same place, such trees would certainly be found with the small branches on their stems and roots, if not in the whole, at least in part, and those not decayed, for in the very same places there have been found in the Peat, hazle-nuts, with their shells entire.

We know that these trees lye eight or ten feet below the surface of the Peat, which surface is, in some places, four feet lower than the sea at low water; how, then, can it be conceived that those trees could have grown in such low lands, unless we suppose that the level of the sea was at that time full twenty feet lower than it is at present?

To this may be added, what I have myself been an eye-witness to, that a violent storm from the North-West has so agitated that river which we call Hollands Diep, or Haring Vliet, as to tear up from the bottom large portions of a substance similar to our Peat, but so light, as to be carried by the waves against the banks, and there left, sometimes in pieces larger than a cart-load, which substance I was told the poorer sort of people carried away for fuel. Now, it is impossible that this Peat-like substance raised from the bottom of the Haring Vliet, and which, like Peat, is composed of leaves, small fibres of the roots of trees, and other vegetable substances (and who knows how deep the bed thereof may be?) could ever have grown in that place.

I once saw Peat taken up from the depth of ten feet, in a watery place, where it had never before been dug. I examined the texture of it, and found it in part to consist of an herb called heath, which herb does not grow in our Peat-lands. And I have also seen Peat dug up at a considerable depth under the sands, not in regular strata or beds, but in broken interrupted patches, and sometimes in a large body collected. This Peat I examined, and found that it consisted of leaves of trees, the roots of grass, the stalks of leaves, and very small pieces of wood; in short, there is no vegetable substance that grows wild of itself, but what, upon an accurate investigation, will be found among Peat.

Some years ago, being on a journey at a small distance on this side of Haerlem, I saw in a meadow by the road side, a labourer digging in the earth in a cavity as deep as an ordinary man's height; and, being curious to know what he was taking up, I alighted from my carriage, and found that it was Peat which was laid by in pieces to dry for firing.

In the place where this man was digging, the Peat lay only in small parcels, or collected portions, and near the same spot there was not any token or appearance of Peat. I was at the same time surprized, to see lying on the sand among the Peat, a certain substance of a fine blue colour, and I was told, that, near the place, it had been found in a larger quantity, and enough of it collected to fill a small cask, which had been carried away and sold.

At another time, in passing through the town of Helvoetsluys, I observed before the houses of several poor people, parcels of Peat piled up to dry, and I was told that it was good fuel, but produced a disagreeable smell, and that it had been dug out in enlarging the dock for ships; and on breaking some of this Peat in pieces, I perceived in it some small shining particles, which induced me to carry home a small quantity of it, that I might examine it by the microscope.

I was informed, that this Peat was dug in a place where there had formerly been a dyke, or bank against the sea, and that the peat did not lie in a regular bed, but only in three places, and that under it was the kind of sand we call klapzand, all which, upon examination, I found to be as related. Hereupon I concluded, that this sand, called klapzand, had in former times been the sea-shore, and that the Peat had by floods been brought to the three places where it was now found, and afterwards covered with sand from the sea, or that washed down the river.

On my return home, I examined this Peat by the microscope, and found, that the before mentioned shining particles were the seeds of some plant, which, if they had been larger, might have been taken for beans, but these were scarcely the fifteenth part of an inch in diameter. Other shining particles I also observed in this Peat, which, upon a more accurate examination, I found to be pieces of the skins of those flying insects which are produced by transmutation from maggots or caterpillars, who hide themselves in the earth; and, among others, I saw some pieces of an insect of the beetle kind, which, as it frequently

creeps into the earth, has its wings covered with a kind of shell or case for their defence, in like manner as we observe in those insects which are called by children cockchafers and ladybirds.

I also discovered divers pieces of the bodies of various small animals, in which I could distinguish those little cavities or spots which are observed on insects, particularly on the cases covering the wings; also on some of these fragments I saw very minute hairs, such as the bodies of insects are generally covered with, likewise some fragments of wings with hairs on them. I found also a kind of sting of some insect, and at the extremity of it an aperture, such as is seen in the sting of a scorpion; in a word, I found an incredible number of particles or broken fragments of insects of various kinds and sizes, considering the small quantity of Peat in which they were contained, so that it may fairly be concluded, that all those insects had been promiscuously collected together when the earth on which they lay had first been washed away.

In the same portion of Peat were various particles, appearing to the naked eye like the stalks of grass or plants, and such I found them by the microscope to be, and by it I plainly perceived the tubes or vessels of which they were composed. I also discovered some few particles, which seemed to be the husks of seeds, and others which I imagined were the rinds or bark of twigs.

All these particles, of the many different kinds I have enumerated, were contained within the compass of a portion of Peat not exceeding a cubic inch in size.

From these observations it appears, how incorruptible are some substances, when buried deep under sand and water, when the same substances being exposed to the air, and in frequent agitation, are so divided and broken that they escape our sight, and then we say they perish; and who knows whether this Peat-like substance might not have lain for some thousand years under the sand and sea water before the place became firm land?

It is well known, that not only in Holland, Guelderland, and Utrecht, but also on all the sea-coast, as far as Holstein, much Peat is found; and if it be true, as is generally believed, that not only England and Scotland were formerly united to Ireland, but that the Orcades, Shetland, and Faro, and the other small islands near them, were formerly united (which islands being rocks, or rocky on their shores, are able to resist the force of the sea), and that in these islands this Peat-like substance is also found, we can without much difficulty solve the question, if we suppose that these larger and smaller islands, by violent storms and high tides of the ocean, may have been separated from each other, and that the earth or soil which was then carried away, was covered with various trees, grafs, and herbs; all these substances floating on the sea, might, by the tides and North-West winds, be driven to the places where they now lie; and the trees which we find lying with their roots pointing to the North-West, must of necessity be deposited in that position: for, as the roots of trees are heavier than the upper parts of the stem, those roots must sink deepest in the water, and, being dragged along the bottom of the sea, the stems would be driven foremost, and cause the trees, when washed on the land, to lye with their roots towards the North-West. The heavier substances, as sand and clay, which had constituted the soil so carried away by the sea, would, by their weight, sink to the bottom, and, taking the same course with the Peat, would be thrown upon it, and produce a sandy shore, as we now perceive it.

It is further to be considered, that our rivers, the Rhine and the Maes, do every year bring down with them great quantities of soil, and particularly in the spring time, because at that season, by the sun and rains, the snow is melted on the tops of the high mountains, and, running over the lands, washes away with it great quantities of sand, clay, and earth, and these, by reason of the swift current of those waters, find no rest until the rivers, becoming wider at their mouths,

and meeting also the flood from the sea, their current is diminished, and the sand subsiding, produces shallows. In these shallows, the clay and earthy substances also settle, because in those places the waters have little motion, in proportion to what they have higher up the rivers, and, by this means it is well known that there is a continual increase of dry land in some parts of our shores.

If we observe attentively our sea-coasts, we shall in some places, even those which the sea daily breaks against and washes over, observe large pieces of black earthy matter, very compact and closely cohering, and which lye partly covered with sand, and partly overflowed every tide. These portions of earthy matter so deposited, produce a strong argument, to convince us that our shores thus washed up by the sea, were not merely formed by small quantities of soil gradually deposited, but by large portions or fragments of land. And, who knows how long such fragments of land might, by reason of their gravity, lye at the bottom of the sea before they were thrown upon the shore, which, in all probability, could not be effected otherwise than by violent storms, and that, many years after the shoaly or sandy bottom was first formed.

The magistrates of Leyden had it lately in contemplation, if it could have been done, to make a channel, outlet, or opening for water, into the sea at Catwick, in the place where the Rhine formerly disembogued itself; but they found the undertaking to be impracticable, by reason that the level of the sea was too high at that spot. This, at first, appeared strange to me, as I could not conceive how the sea could obtain a greater altitude than in former ages, seeing there is not a greater portion of waters on our terraqueous globe, than at its first formation. But the difficulty ceased in my mind, when I considered, what quantities of fine sand and slime, or clay, are continually carried down our rivers, insomuch as to make firm land, where formerly it was deep water; and further, what large rivers there are in other parts of the world, all which carry great

quantities of such sand and slime into the sea; whereby, at the mouths of those rivers many levels of marsh land are produced, while on the other hand, most countries far distant from the sea are mountainous.

If we then conclude, that, by all these rivers, a great quantity of sand and earth, and whatever is heavier than the water, is deposited in the sea, it necessarily follows, that the sea must from time to time be more elevated. Again, by earthquakes, large portions or tracts of land are buried in the sea, leaving nothing but lakes in their place; and we have instances of a volcano or burning mountain casting so many rocks and stones into the sea, as to raise islands where before it had been deep water.

In the year 1692, by an earthquake in the island of Jamaica, a large space of land was swallowed up, and converted into a lake; and, at the distance of thirty miles from the sea, two hills, by the side of a river were thrown down, causing the river to take another course; from which new channel, a great quantity of earth must have been carried into the sea: and although the coast of Norway, and that of Ireland, Scotland, and part of England, are rocky cliffs, yet their rivers must continually carry much solid or heavy matter with their waters, and, the beating of the waves against the cliffs, will carry these kinds of substances into the bottom of the sea, and so elevate its surface.

To some persons this assertion may seem strange, as judging that the great extent of the sea bears no proportion to the small quantity of earth which the rivers wash into it; and that therefore, the sea cannot be so much elevated, as to make any perceptible difference in several hundred years.

In order to set this matter in a true point of view, I have made a question with myself: Supposing the mountain called the Peak of Teneriffe, to be sunk in the sea, what elevation would it produce in

the general surface of the water? Now, (considering the whole of this globe to be one third part land, and two thirds water) I compute that the whole surface of the waters would be thereby raised between one fourth and one third of an inch. And, supposing all the rivers in the world, which are very numerous, (for according to our maps Spain and Portugal only, contain one hundred) do yearly carry with their waters into the sea so much earth as is equal in size to one half of the Peak of Teneriffe, the sea would, in the space of one hundred years be elevated nearly two feet.

This being so, it is not to be wondered, that we find our flood tides, in strong winds from the North-West, to rise higher than they were known to do in former times, and that the Rhine, which heretofore fell into the sea at Catwick, cannot now have any outlet that way; and lastly, that on the same account, we are obliged to raise our dykes higher than formerly. Indeed, we may conclude, that if in a course of many years, there should not be more space given to the waters of the ocean, by earthquakes or subterraneous fires, producing cavities in the deep, the low lands near the sea will at length be overflowed.

As to the quantity of land excavated in digging Peat, which some may imagine affords room to the waters, the space of earth or soil so taken away, does not, in my judgment, amount to a thousandth part of the sand and clay which is brought down the rivers, and besides, the places so excavated are, for the most part, afterwards drained.



*On the effects of Acids in the Stomach, and the use of Fish Diet, with
a particular description and examination of the liquor or substance
named Runnet, which is used in the making of Cheese.*

IT is the opinion of many medical persons, that various disorders in the human frame are caused by acid in the stomach, which coagulates the juices ; and some condemn the use of acids, and also of fish, as articles of food. But to these opinions I cannot subscribe, for, at a town in my neighbourhood, where the people get their living by fishing, and principally feed on fish, especially when they are on the sea, the men are very robust and healthy, even to a great age ; and, with respect to myself, I have experienced, that, when my habit of body has been indisposed, I have been greatly refreshed by eating fish, with sauce composed of a mixture of butter and vinegar, and I never found acid sauces disagree with me. It is also my opinion, that a fish diet is more wholesome than flesh, particularly to those persons who do not use much exercise, because fish is more easily comminuted and digested in the stomach and bowels than flesh ; and, as flesh affords a more nutritious substance, such superabundant nutriment is, in my opinion the source of many diseases. And, I think it may be made appear, that the coagulation or curdling of food in the stomach, when caused by acid, is not prejudicial, but rather conducive to health.

In the markets which are held weekly in our town, it is usual to expose to sale, that part of the intestines of calves which is called

the Maw ; this is salted, and kept in casks, and, with the pickle in which it is preserved, goes by the name of Runnet. It is purchased by farmers, and when poured on milk* curdles it, of which curd, cheese is made. Some of this pickle I purchased, in order to examine it more accurately, but was obstructed in my enquiry, by the numbers of saline particles in it.

I therefore purposed to procure from a butcher, some of the liquor when newly taken out of the maw, as soon as the animal was killed ; and I was informed, that if a calf had swallowed any milk a few hours before it was killed, there would be found in its maw a quantity of coagulated or curdled milk, which it was customary for the butchers to take out and preserve with salt in a jar, (some of which curd was shewn to me), in order to sell the same to the farmers, who found by experience that a small portion of this curdled milk, was of more strength or virtue for their purpose, than the liquor in which the maw was pickled.

I then went to another butcher's, where I saw the maw of a calf, wherein, although the animal had not sucked for the space of twenty four hours before it was killed, I perceived some portions of curdled milk, larger than a walnut ; these I caused to be washed in clean water, and carried them home with me, and I was much surprized to find them as hard to the touch as new made cheese.

This curdled milk I put into a glass, and poured on it rain water, so as to cover it about an inch, and then broke the curd into smaller pieces, in order that the saline particles, if any there were in it, might be dissolved by the water ; and, after it had stood thus for some hours, I strained the water through a filtering paper, into a new and perfectly clean glass.

* *Rinnen* in German, and *ronnen* or *runnen* in Dutch, mean to curdle ; this gives us the true derivation of the word Runnet.

Some of this filtered water I poured on a portion of wine, in order to see whether it would have any effect on the saline particles which are in wine, but, after it had stood several hours, I could not perceive any alteration; I therefore determined to try the experiment with vinegar. And, as the vinegar which is commonly sold, is for the most part adulterated, I took white wine vinegar, which I had kept with marygold-leaves in it for five and twenty years, and was uncommonly strong, and mixed with it a small quantity of the before mentioned liquor, but I saw no other saline particles in it than those which are found in vinegar. I observed, indeed, several globules of oil, which in all probability proceeded from the marygold flowers.

But, when I took a small quantity of new milk, and mixed with it a very little of the before mentioned water, on bringing it before my eye as soon as I possibly could, I saw most of those round particles which cause its white colour, curdled together, and an inconceivable number of smaller particles, swimming among the curdled ones, from whence I concluded, that these smaller particles were of a different nature from the coagulated ones; I also saw in the fluid or whey various pellucid globules of different sizes, the smallest of which were no larger than globules of blood, and the largest of these pellucid globules were twenty-five times that size; all these I concluded to be those particles in the milk, of which butter is composed.

From these observations it appears, that this liquor called Runnet, which coagulates or curdles milk, does not take any effect on wine or vinegar, neither of which are adapted to the food of calves.

I was informed by the butcher, that the same curdling of milk, took place in the stomachs of sucking lambs; and moreover, that if lambs were taken from their dams and fattened with cow's milk, it would be curdled in larger quantities, by reason, (as he judiciously added) that ewes milk has more particles of fat in it than that of cows.

After this, I mixed new milk with a large quantity of Runnet, to see whether those smaller particles which I have before mentioned to have been swimming in the whey, would thereby be coagulated, but they still continued to preserve their figure.

Upon examining the before-mentioned filtered liquor by the microscope, I saw in it an inconceivable number of uncommonly minute particles, to which, by reason of their exceeding smallness, I could not give any other name than that of globules.

Whether the globules or salts in the Runnet, have such an effect on rain water, as to cause any of its particles to coagulate, so as to become visible by the microscope, I have not yet been able to discover.

I several times tried the experiment of pricking my finger with a needle, and, immediately mixed some of this liquor with the blood, to see whether any of its particles would thereby be coagulated: on viewing the same through the microscope, it exhibited a curious and pleasant spectacle of vast numbers of the globules of blood, rolling one over another, but they were so far from being coagulated by the mixture, that they seemed more fluid than before.

After this mixture had stood about the space of half a minute, I perceived in it many small pellucid particles, which by degrees grew larger, but yet were so minute, and so much covered by the circumjacent particles, that I could not clearly discover their figure; but, to the best of my judgment, they were irregular saline particles, appearing all of different shapes, and adhering together, in like manner as we observe in sugar-candy. Now, whether this appearance was composed of salts in the blood, or salts in the milk, or both, I am not able to discover.

I several times applied a drop of the before-mentioned filtered liquor to my tongue, and I judged it to have more of a bitter than an acid taste; whereupon I considered, whether its property to curdle milk, might not be derived from the gall.

I therefore went to a butcher's, to see whether the gall was not emptied into the maw, but I found that the gall bladder did not discharge its contents into the maw, but farther down, where the bowel grows narrower; this gall bladder I caused to be cut off so as to leave the vessel through which the gall passes, joined to the bowel, and having bound both ends of these with a thread, I inflated the gall-vessel with wind, but I found the parts to be so contrived that not the least portion of water, or even of air, could pass out of it into the maw.

When some of this Runnet had stood with a little water on it in a glass, for the space of two days, it acquired as acrid a smell, as we perceive in four curdled milk.

I at one time, received from a butcher, the gall bladder of a calf, which was entirely void of gall, whence I supposed that its contents had been spilled by accident, but I afterwards understood that no gall had been in it, and that the like appearance was often observed.

But, what shall we say, when we see in how high estimation tobacco is held, and acids altogether condemned; as if all our bodies were exactly of the same disposition or constitution.

For my part, I have for many years been used to smoke tobacco for the cure of the tooth-ach, but I have often found that before I smoked half a pipe, I was so sick, as to be obliged to lie down near the fire, and so much disordered, that I could not even endure to be spoken to; whereas, on the contrary, every kind of acid, whether used in food, or taken by itself, agrees perfectly well with me. In short, we can much better judge for ourselves as to what agrees or disagrees with our constitutions, than pretend to advise other people what is good diet, or the contrary.

With regard to the curdled milk, which I have mentioned to be taken out of the calf in hard pieces, it seems to me probable, that the milk at first was but lightly curdled, and that the frequent contrac-

tions of the bowels where it lay, which in the course of nature are performed many times in a minute, were the cause of its being found in that state.

Seeing now, how powerfully coagulation is performed in animals, we may conclude, that something of the same kind must take place with the food in our own stomachs, in order to render the same nutritive to us. And who can tell, how far such coagulation may take place, not only with milk, but also with wine, vinegar, salt, and other parts of our food? This, however, is certain, that if a sucking child casts up the milk, on account of having swallowed more than its stomach can contain, such milk, though just before taken from the breast, is in a curdled state; consequently we must conclude, that coagulation in our stomachs is a necessary part of the animal economy.

If milk in the stomachs of small animals was not curdled, it would in a few hours pass through their intestines, and afford but little nourishment to their bodies. And, in this opinion I have been confirmed by the experience of the butchers, from whom I find, that when the excrements of calves or sucking lambs are thin and fluid, they thrive but little, and, that at those times, no curdled milk is found in their stomachs.

I am aware, that these my observations, may displease some persons, as thinking that herein I am going out of my province; but, those considerations weigh little with me, forasmuch as every judicious person knows, that Physicians themselves, in many things proceed merely by guesses, and therefore, I assume to myself the liberty of offering my conjectures on this subject.



ADDITION BY THE TRANSLATOR.

Almost all the arts, which contribute to the support or comfort of human life, have been the result of long and repeated experience. I will instance in the two most necessary articles of food, which are bread and beer, respecting which, a celebrated writer of the last age thus expresses himself:—"The arts of
 "brewing and making bread have, by slow degrees been brought to the perfection they now are in, but, to have invented them at once, and, * *à priori*,
 "would have required more knowledge and deeper insight into the nature of
 "fermentation, than the greatest Philosopher has hitherto been endowed with;
 "yet the fruits of both, are now enjoyed by the meanest of our species."

Cheese, however, another principal article of food, at least among the poor, was most probably brought into use, *à priori*, by adverting to the change made in milk, from a fluid to a solid, in the stomach of the calf, and by imitating nature in the manner described in the preceding Essay. To preserve the concreted or hardened substance, in a wholesome state, for a length of time, human invention added salt, and, by these two easy operations, is produced that, which is now a luxury to the rich, and a support to the poor.

How the change in milk, by the mixture of Runnet, is produced, Mr. Leeuwenhoek's industry, we see, has not been able to discover; we can only therefore admire the manner in which nature operates, to produce this effect. For, there is no other known substance that so effectually curdles milk, and, though the taste of Runnet is of itself very nauseous, yet none of this disagreeable taste is imparted to the curd; on the contrary, that which is called cream cheese, or new cheese, being merely the curd, without any mixture of salt, is of a sweet and delicious taste, and is produced as a dainty at our tables.

* The expression, *à priori*, means, in logic, or in practice, to argue or to act upon known and established principles, from whence a certain conclusion or effect ensues; *à posteriori* means, where, arguing from the effect, we trace it backwards to its cause.

Of the Snail or Insect found on the Vine, also on the nature of Sage, and whence its virtue proceeds; with some observations on the manner in which different animals emit their poison.

A Gentleman of some consequence in this country, upon a certain time, put into my hands, a parcel of small whitish eggs, together with some dry earth, in which they were found; and desired that I would endeavour to discover what species of animal would be produced from them. The axis of these eggs was nearly equal to one fifteenth part of an inch.

One of these I dissected, and found in it a thin fluid, mixed with round particles, or globules; the rest of them I put into a glass, but their contents in a few days entirely evaporated, and the shells, which were very brittle and tender, upon the liquid they contained being exhausted, became shrivelled, so that no living creature proceeded from them.

The following year, the same gentleman brought to me some more of those kind of eggs, which I treated in the same manner as the former, but with no better success.

In the month of July, in the third year, I received from the same person a larger parcel of those eggs, which were mixed with about an handful of moist earth.

Seeing this, I began to consider, that perhaps, the reason why the liquor being evaporated from the former eggs, had thereby prevented their producing any living creature, was, that in dry earth they be-

came barren, and that in their nature they required to be kept moist; consequently, that if I treated them in the same manner as the former, I should never obtain my wish to discover their species. I therefore put these, and the moist earth wherein they lay, into a glass tube, about ten inches long, and three quarters of an inch wide, one end of which I had closed together by heat, and the other I stopped with a cork, by which means whatever moisture might evaporate from the earth, would be confined by the glass, and, there condensing, the greater part of it would fall back on the earth, and keep it, and the eggs, always moist.

This tube I placed in my closet, so as to be continually in the way of my notice, and, after some days, I saw, to my great surprize, two small * Snails, of that species which infest the branches of vines, (and which are called by us Wyngaart-flakken, Vine-snails or Vine-flugs) on the inside of the tube, and which had crept out of the earth contained in it.

I then took out of the tube an egg, or rather what was now become a small Snail, with part of the egg shell adhering to it, and put it into a smaller tube, in order to examine it by the microscope more accurately; and thereupon I perceived in one of the horns a very rapid motion, performed in a vessel, apparently an artery, and which I judged to be about one fourth part the size of an hair. This motion was not an uniform or continued one, but by fits, or pulses, and, so quick, that I judged the juices in the vessel were propelled forward, three times within the period of one pulsation in the human body; and I concluded, that this vessel must certainly be an artery, and not far distant from the heart, because the quick pulsations I have noted, could not, otherwise, have been so distinctly seen.

The next morning this small Snail was dead; as I guessed, for want of food, for the others of the same size, which were in the larger

* Mr. Leeuwenhoek has not given a figure of this animal.

tube with the earth, continued alive; the next day more of the same kind of Snails came out of the eggs, and the third day many more.

I often contemplated one of these Snails, while adhering to the inside of the glass tube, and, with great pleasure, I saw through its shell (which was so pellucid as to transmit the light) a part of its body not larger than a grain of sand, and of an oval shape, which alternately was contracted and extended, each alternate motion being performed in the same space of time as is required to pronounce distinctly a word of four syllables. This little point or corpuscle, I deemed to be the creature's lungs, and the reciprocating motion, that of respiration.

I have formerly often dissected these kind of Snails found on Vines, chusing for that purpose the largest I could find, in order, if possible, to discover the manner of their generation, and whether any young ones were to be found in them, but hitherto without any success; and now, almost by accident, and with little trouble, I plainly perceived that these creatures were propagated by laying eggs.

It has frequently been matter of great wonder to me, to observe in the spring, young Snails of this species on the Vine branches, when I could not conceive, how they could have been bred and brought forth so early in the season. But, since it now appears, that they are produced from eggs, the difficulty ceases, because we can easily conceive how these animals may be hid in the earth all the winter in the egg, and break out from thence, as soon as the first warmth of the spring returns.

I have likewise often observed full grown Snails of this species, whose shells were covered with earth or clay, as if they had been newly dug out of the ground, and never could satisfy myself as to the cause; but this is also now accounted for, because, as they must creep into the earth to deposit their eggs, it is natural to suppose that some portions of earth or clay may be left sticking to their shells or horns. And, if any person should wonder how these creatures can

creep into the earth, I can satisfy him in that point, from my own experience ; for I have frequently seen, after I had picked several of them off the tree, and not only thrown them on the ground, but pressed them with violence into the earth, by stamping on them with my foot, yet, in a short time, if their shells escaped unhurt, they would find their way out again.

In the month of August, I invited the friend I have mentioned, to my house, and acquainted him with the manner I had treated the eggs he had sent me, and shewed him the Snails which they had produced, with which he was greatly pleased ; and told me he had rather supposed, that the species of lizard commonly called Efts would have been the produce. The next day, he brought to me a very large Snail of this species, the surface of whose shell was covered with moist earth, just as if it had newly crept out of the ground ; and he informed me, that, while he was bringing it, he perceived it lay an egg. Hereupon, I put this Snail into a glass tube, about ten inches long, and wide enough to give it full liberty of moving about ; and within half an hour it laid seven eggs, which I perceived sticking to the glass, and in two hours time as many more ; but, when I next examined it, I found that in creeping about the glass it had broken them all, and in two days it died, as I suppose for want of food, without laying any more eggs.

The small Snails, which, as I before mentioned, were produced from the eggs, did not live above two or three days, and I perceived that the shells from whence they had issued were very white, but the remainder of the eggs which had not produced any young ones, and were barren, were of a dark colour, and of a watery appearance.

It being now demonstrated by the foregoing observations, that these Snails are produced from eggs, the old established error must be abandoned, which those adopt, who dream that these creatures are produced from corruption, or the decayed leaves of trees ; and

thence conclude, that, if such leaves are not taken out of gardens, these Snails will be bred from them. Whereas, we ought rather, on considering the matter, to say, that if the leaves which fall in autumn are left in gardens, the eggs deposited by these Insects in the ground, the surface of which is covered with such leaves, will be the better defended from the winter's cold, and consequently more of those animals will be produced in the following summer.

A certain Author, of the name of Kircher, having published to the world, that he had, by his microscope, discovered on the leaves of Sage something like a spider's web, woven by some small insect, and having thereupon founded an assertion, that those who should eat of Sage leaves, without washing them, would be poisoned, I was requested by some learned friends, to examine into the truth of this assertion.

I had many years before this time, frequently inspected the leaves of Sage, and always found that they were, in many places, covered with small globules, but I never perceived on them any animalcules, nor their eggs, even by the assistance of the microscope.

Upon this occasion, I procured some Sage, not only the green sort, but that, which, because its leaves are yellow at the edges, is called variegated Sage. This I examined by the microscope, and perceived the leaves to be covered with many capillary or hairy parts, too small to be discerned by the naked eye; and so closely set together, that there was not a place in the leaves, of the breadth of an hair without them, and, I cannot give them a better name, than capillaments, or small hairs, because, like the hairs of animals, they all terminate in a sharp point. And I suppose, that Kircher had imagined these capillaments to be the webs of spiders.

At the extremities of many of these capillaments, I perceived certain globules, which, through the microscope, appeared no larger

than grains of sand seen by the naked eye; and these globules seemed to me to be filled with an oily substance. But I could not discern the least trace of any living animalcules on the surface of the leaves, and I am certain, that, had there been any such, though an hundred millions of degrees less than a grain of sand, they would have been visible by my microscope.

This oil, wherein the virtue of Sage consists, is produced on every leaf of it in such abundance, as no one would believe, but from experience; inasmuch that one can scarcely touch a leaf of Sage, but an incredible quantity of oily particles will adhere to the fingers.

My admiration was greatly excited, by observing that the greater number of the capillaments I have mentioned, were formed with three joints, and some, which stood on the vessels of the leaves, with four. These joints I do not remember to have seen in the capillaments on any other leaf, but whether that is to be attributed to my want of attention, I do not know.

When Sage is dried, its leaves exhibit a whitish colour, and that is caused by these capillaments, which, lying thick one on another, do, by their transparency, produce that whiteness.

This same Kircher, in his writings, gives it as his opinion, that Sage, and also Fennel, are very wholesome herbs, but, that in them is produced a maggot, which, being inadvertently eaten, will cause grievous symptoms, and even death itself; and he moreover pretends to have found by experience, that there is no plant which does not breed some maggot or moth; but surely, if he had been provided with a good microscope, and had understood how to use it in the dissection and examination of minute animals, he never could have broached such absurdities.

For my part, it is my fixed and settled opinion, that no leaf, no tree, nor any root, ever did, or ever can, produce or breed any animal endowed with life and motion. But, a small animal may lay its eggs, or

deposit its young, on the leaf or fruit of a tree, which young one, when deposited, or when hatched from the egg, may make its way into the leaf or fruit, and there find nourishment to promote its growth.

It is an established axiom among Philosophers, that, nothing can come of nothing; how then can a being or substance void of motion, produce a creature endued with motion and life? And this is certain, that, whenever we dissect or examine small animals, the wonderful fabrick of their bodies, both externally and internally, strikes us with astonishment.

As to the opinion, that venomous animals do shed their poison on fruits or leaves, I do not see that this can be said of the Scorpion, nor that poisonous serpent called the Rattle Snake, neither of the Spider, nor the Indian Millepeda, because, as far as I can understand, they have not power to hurt, by spitting or voiding their poison on any object, because they cannot cast it to any distance, but they do mischief, by injecting it into a wound made in the flesh. But, it is possible for the Frog and Toad to infect plants with their venom, for I have more than once observed those animals, when irritated, eject a kind of water, in a stream, from their posteriors, which water possesses an extraordinary corrosive acrimony. This property was first experienced here, by a respectable person, who, in fishing for Jack, used young frogs for a bait; and once, while he was fixing a frog to his hook, the animal on a sudden scattered a little of this liquor into his eye, which produced an excruciating pain in the part.

I have often taken notice of a large dog, who was very eager in the pursuit of mice, which he would swallow whole, without chewing. He was also very fond of hunting frogs and toads, and, when he had killed them, by biting, he used to throw them away; but at those times his mouth was entirely covered with froth or foam, which I attributed to the liquor emitted by them. This was most particularly the case,

when he caught a toad, for then, he appeared almost mad, violently shaking his head, and, great quantities of froth or flaver issuing out of his mouth; but he was accustomed, before he began to bite the toads, repeatedly to take them in his mouth, and dash them against the ground.

This virulent liquid in frogs and toads, they do not, in my opinion, emit, except upon extraordinary occasions, when they are irritated, for it is a natural instinct in all animals, carefully to preserve that, which Nature has given them for their defence. So the Scorpion, whose weapon of defence is his sting, does, while creeping or running along, carry the point of the sting turned inward, towards his body, in order to preserve it from injury.

This sagacity, and the other faculties we observe in animals, cannot be supposed to be produced spontaneously, nor that, with the creature it is bred from corruption or putrefaction, but, we ought to lay it down as a certain position, that these faculties implanted in animals, at the Beginning, have been, by a constant succession, transmitted to their offspring; forasmuch as we are not to suppose that any new animal, or species of animals, is created at this day. In a word, the make and structure of every creature, and the powers implanted in it, must, in my judgment, be ascribed to God alone, the Creator of the Universe.



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On Wheat, and the manner of its vegetation; the nature of the several component parts of that grain explained, and their figures described as seen by the microscope.

ALL feeds contain in them the rudiments, or first beginning plants, of their respective species; that is, the part which, in the progress of vegetation, shoots upwards, and forms the stalk or stem, and that, which penetrates downwards into the earth, and is called the root. Seeds do also, for the most part, contain a farinaceous or mealy substance, which affords nourishment to the young plants until the roots are of a sufficient size for extracting supplies from the earth, to continue and perfect their growth.

Among many other feeds, I have particularly examined the grains of Wheat; and, in them, the young plant I have mentioned, before it began to vegetate, having first either put them in water for a short time, or held a few grains in my mouth, merely to moisten the outward membranes, whereby they could the easier be taken off. And, having separated the two external membranes which cover the young plant, I took it out from the grain, and placed it before the microscope, when it appeared to me to be composed of nothing else than a collection of ascending vessels, with some flexures or bendings in them, and some minute tubercles or pimples, which pimples I conceived to be only caused by the evaporating of the moisture.

In Plate VI. *fig.* 1, ABCDEF, is the whole of this beginning
Y

ning of the plant, magnified: E F D, are the parts or points from whence not only three distinct roots will grow, but they are also the beginnings of three several spires or stalks of Wheat; for the minute protuberances which appear at F A, and C D, are two distinct plants: so that, from every grain of Wheat (which is well worthy of observation) there will arise, not merely a single stalk, but three distinct ones, which are formed in the seed itself. And as, when speaking of artichokes, we call the principal or uppermost fruit, the parent artichoke, and the others chicken artichokes, so, in the instance before us, we may properly name the uppermost plant, which appears at B, and whose root projects lower than all the rest at E, the parent plant, and the two smaller ones, at F A, and D C, the two chickens or suckers.

In order to form a computation of the proportionable size of these first formed plants, I placed them beside an entire grain, which I judged to be four times their size both in length and thickness, whence it follows, that each grain of Wheat is sixty-four times larger than the three several young plants formed in it, and which are to receive nourishment from it, in the beginning of their vegetation.

I cut off a piece of this young plant, by a tranverse section, across the part where the three vegetative principles I have described are situated, or at the place in the figure from F to D, only to shew how, and in what order, the roots (or that which is the place or source of the roots and plants in this seed) do lie in respect of each other; and also, to point out the multitudes of vessels formed in them.

In *fig. 2.* ABC, is the first or outward membrane or covering, which encloses both the plant, and the whole circumference of the grain of Wheat, and is composed of nothing but vessels extending lengthwise, and which, being cut transversely, appear in this membrane as they are shewn in the figure, particularly at B, where may be seen a few of these vessels, presenting part of their sides to the eye. The second membrane or covering, is in part shewn at D E F.

The reason why these membranes appear at so great a distance from HIK, the three young plants, is, that this grain of Wheat was very much dried, and therefore, in the cutting, the membranes were easily separated from the farinaceous part, where the young plants are placed; but when the plants and the mealy substance, lying in the space marked by the letters DHIKFGD, are a little moistened, they very soon swell so much, as to fill up the whole space HEKI. This, however, is the case in but few grains of Wheat, for, when the young plants, and the substance wherein they lie, contract in drying, the membranes which inclose them contract likewise, they being, generally, all closely united or adhering together.

At the letters HIK, are shewn the three beginning stalks, or roots, of the future plants, as cut transversely; and, in these, the vessels would have been much more conspicuous than here represented, had it not been, that in the cutting them (although the knife I used was very sharp) they were filled up or stopped; but, though by moistening, and then cutting them, the vessels appeared more distinct, yet, no sooner did the moisture evaporate, than they contracted themselves in such an irregular manner, as to be much less conspicuous than at first. And, as to those which were visible, the limner continually complained, that it was impossible for him to represent in his drawing, the multitudes of slender vessels which he saw.

The substance wherein the young plants of Wheat are contained, (which is very little in quantity) appears of a different colour from the mealy part of the grain, by reason, that the globules which compose it, are not, singly, so pellucid, and therefore do not, altogether, appear so white, as the meal which composes the greatest part of Wheat. And these two substances are divided from each other, by a third, of a still brighter colour than the white meal, as in the figure is shewn at DGF.

If, in this figure, I had caused the whole circumference of the grain,

thus cut tranſverſely, and magnified, to be delineated, it would have occupied too much ſpace in the paper ; and therefore, I only included ſo much of the mealy part of the grain, as is expreſſed between the letters, a, D, G, F, c.

I have given a figure of the veſſels compoſing the external ſhell, huſk, or covering of Wheat, becauſe, contrary to what is generally obſerved, they do not end in a tubular ſhape, but grow out into a kind of hairs.

Fig. 3, GHIKLM repreſents a very ſmall piece of this outward huſk, which, when ground, and ſeparated from the meal, is denominated Bran. Here, not only are to be ſeen the multitudes of veſſels whereof it conſiſts, but alſo, how at their extremities, they grow out beyond the grain, and terminate in hairy points, as at I K L.

The ſecond membrane, lying within the firſt, exhibits a curious ſpectacle, on account of the tranſverſe courſe of the veſſels, in a different direction from the former ; and at *fig. 4*, ABCDEF, is ſhewn an exceeding ſmall particle of it, wherein, though it is no more than can be covered by a grain of ſand, the wonderful courſe of thoſe numerous minute veſſels is plainly to be ſeen. And, as it is truly ſaid, that nothing is made in vain, we cannot ſufficiently admire this, and ſimilar objects, when viewed by the microſcope.

In the ſame figure, at D and E, may be ſeen ſome of thoſe globules which compoſe the mealy ſubſtance of Wheat, lying within, what ſeemed to me at firſt, an exquisitely thin pellicle, like a third membrane, but was, in reality, only the finer part of the meal.

I many times endeavoured to trace in the young plant, while in the feed, the veſtige or firſt formation of the ear, but all my endeavours, even with the aſſiſtance of my microſcopes, were fruitleſs, though I was well aſſured in my own mind, that it did there exiſt : at length, to ſatiſfy myſelf, if poſſible, in this reſpect, I took a ſmall braſs box, and almoſt filled it with that ſort of white ſand called ſcowering ſand, on the ſurface of which I placed, upright, about fixteen grains of Wheat,

and, after strewing more sand on them, to about the thickness of the back of a knife, I moistened the sand with rain water ; and, because the weather was extremely cold, it being in the midst of winter, I carried the box about with me in my pocket.

At the end of four days, some of the grains had put forth shoots to the breadth of a finger : one of these shoots, I cut off close to its root, and, opening it, I took out the middle part of the plant, wherein, by the help of the microscope, I perceived some minute leaves, and, from their appearance, I was well assured that the ear between them had increased in size, though I could not distinctly perceive it.

After carrying the box and the remaining grains in my pocket four days longer, I opened it again, and, taking out from one of the shoots that part which consisted of the innermost leaf, immediately inclosing the ear, I placed it before the microscope, directing the limner to make a drawing of it, as it appeared to him. This is shewn at *fig. 5.* A B C D, where A B D, is the young ear, and B C D, the inner leaf inclosing it.

At the end of four days more, being the twelfth day, I opened another of the grains, and, having separated the young leaves a little asunder, I was much more confident than before, that I discerned the ear ; this also I caused to be drawn from the microscope, as at *fig. 6.* E F G H.

From these observations we may be fully assured, that warmth and water, will, of themselves alone, promote the growth of plants. And also, that God, the all-wise Creator of the Universe, does not create any new species of Things on this Earth, but that, at the Beginning, he so ordained and constituted all things, that, his Creation being perfect, the seeds of plants, when come to maturity, shall produce or contain in themselves (however undiscoverable by us) the part or vegetative principle of the future plant, which, in its due time will be produced, and that, in all respects conformable to the

original plant. And this, I take to be a certain truth, which prevails not only in plants, but in all living creatures whatsoever.

I was desirous to examine, whether in the vegetation of corn, there would be as great a number of radicles proceed from the first root, as I had observed in grafs, and for this purpose, I took a glafs tube, about half an inch in diameter, and three inches long; having stopped this at one end, I filled it rather more than two third parts with dry sand, which I moistened with rain water, and pressed it gently together to keep it in its place, and then deposited it in three grains of Wheat, stopping also the other end.

This glafs tube I frequently carried in my pocket, and in three or four days, the Wheat began to put forth roots. On the seventh day, the roots were so far grown, that I could most plainly discern them to be composed of wonderfully minute tubes, each of which was formed with joints, as are to be seen in reeds or straws.

The diameter of these roots was, as near as I could compute, about the sixtieth part of an inch, and, at the extremities, they were obtuse or rounding, like the ends of those quills which are taken out of the wings of birds: the surface of them was very smooth and shining, without any appearance of radicles issuing from them, excepting near the grain, where numbers of exquisitely minute radicles were to be seen.

On the eighth day, the young germ or shoot had grown to the length of three quarters of an inch, the roots were also so far grown as to reach the bottom of the tube, whereupon I took out the cork, and they then protruded themselves out of the tube, and I hoped to have discovered in them, whether there were the same joints in the small radicles as in the larger roots; but, in the space of half a minute, the moisture in them was so evaporated, that they became contracted into irregular shapes.

With regard to the size of these excessively minute radicles, I made the following estimate, as far as my eye could judge. Supposing the diameter of them to be as 1, that of the larger root from which they proceeded must be considered as 20, and consequently, 400 of these slender radicles taken together were equal to the size of the larger root. Now, the diameter of this larger root being, as before observed, the sixtieth part of an inch, 3600 of those roots will be equal to a cylinder of an inch diameter; and if this number be multiplied by 400, it follows, that 1,440,000 of the smallest radicles are altogether equal to a cylinder the size of an inch.

This being the case, we may naturally conclude, that when any plant is pulled up by the roots, such slender radicles as these, not only escape our sight, but must almost all be broken off, unless the earth or moist sand which surrounds them adhere to, or is taken up with them.

After these very slender radicles I have described, had remained in the tube three or four days, those parts of them which did not touch either the sand or the glass, and were exposed only to the air within the cavity, were so dried up and contracted into irregular forms, that they appeared like parcels of wool, or the threads of fine linen tangled together.

In the month of April, I took up in a field, which in the preceding autumn had been sown with Wheat, some of the young blades or shoots, with their roots, and the earth adhering to them: and upon examining these, I observed nothing visible, except the largest shoot or parent plant, which was by far the largest, and had shot up much the highest. To shew the size of this plant, I caused a drawing to be made of it, which is to be seen at *fig. 7*, WXYZ; and in this plant the blade being shot up to the height of about four inches, the joints, or knots in the stalk, were already formed, the young ear lying at the end next to the root, at W.

This plant, represented at *fig. 7*, I cut open, and took in pieces, until I perceived the smallest leaves of all, which as I may say, surrounded the ear; these also I took off, and then the ear itself was visible, which, viewed through the microscope, appeared as at *fig. 8*, ABCDE. But, I did not deliver this Object to the Limner, until I had dissected several of the young plants, and found, that they were all exactly of the same figure.

At the expiration of nine days from this time, I examined more of the young blades of Wheat, but did not perceive any change in the ear worthy of note, except that it was grown somewhat higher from the root, and that the joints or knots in the stalk, were more plainly to be distinguished.

The stems or stalks of Wheat, which, after the grain has been threshed out from the ear, are denominated Straw, appear to the eye wonderfully smooth and shining, the outer coat of them being composed for the greater part, of vessels incredibly slender, with here and there a few larger ones intermixed; the inner part is composed of larger vessels, all which I have represented as nearly as possible to Nature, in the following figure.

Fig. 9, ABCDEF is a very small piece of Straw, cut transversely, and seen through the microscope: any person, by considering what proportion the arch, or curved external part of it, marked AF, bears to a circle, and, comparing the same with so much of the known diameter of a Straw, may easily conceive the natural size of the particle here represented.

ABEF, is the bark or outer coat, composed of the vessels before described; GGGG, are the vessels of which the inner part for the most part consists; they are of four, five, and six sides, according as, at their first formation, their shape is accommodated to those adjoining them.

HHHH, are vessels intermixed with the last mentioned ones, and

containing in them still smaller vessels; in these vessels I have seen the juices (at the time the Wheat stalks are growing) running with a wonderfully rapid course; and, through the joints or valves in those vessels marked G, the juice was carried upwards, which juice was for the greatest part composed of globules; and when these globules came to pass the valves where the passage through the vessels is very narrow, they assumed an oblong figure, until they came into a larger space, when they reassumed their pristine globular shape.

Fig. 10 represents these ascending vessels cut longitudinally, and seen through the microscope, being the same which in *fig. 9*, are marked GG: at IIII, are the valves I have mentioned, and, in those parts, the passages through the vessels are the most narrow or confined of all.

The stalks of Wheat, are formed of none other than perpendicular or ascending vessels; and that, in my judgment, is the reason, why they are furnished with a kind of joints or knots, at certain intervals, in order to give strength to them; and that, without such joints, the stalk would not be able to support the ear, which is its fruit. This is also the case with grasses, and likewise with reeds, for the same reason; and it also obtains in the bodies of some trees. In these northern parts, indeed, all trees are provided with horizontal vessels, whereby they have a sufficient strength; but, in the warmer climates, where many of the trees have no other than perpendicular vessels, such as is the cocoa-nut tree, the want of horizontal vessels is compensated, by numbers of these kind of joints, formed at short intervals, through the whole length of the tree.

The farinaceous or mealy part, of which the grains of Wheat are principally composed, consists of those minute globules I have before noticed. These globules are, singly, transparent, and lie closely compacted within a kind of membranes, so exquisitely thin and trans-

parent, that, in some places, their texture is not to be discerned. A very small particle of one of these membranes, as it appeared upon the grain being cut longitudinally, is shewn at *fig. 11*, EFGH; within these membranes the globules of meal are inclosed, as it were, in cells; and, at H, some of those cells are represented, filled with the globules of meal: the natural size of this figure, is no more than can be covered by a common grain of sand.

The globules of meal, are of very different sizes, some being more than an hundred times larger than others, and some so small, that they almost escape the view of the microscope. In order to give the reader some general idea of their minuteness, I took one of the larger grains of that sort of pellucid sand, used in scowering or grinding; this grain of sand, together with some of the globules of meal adhering to it, I caused to be drawn from the microscope, as at *fig. 12*, ABCDE. In the same figure, FGH denote a smaller grain of sand adjoining to the former. IKLM are some of the larger and smaller globules of meal, lying near the grains of sand.

I had at first imagined these mealy particles to be quite globular, but I afterwards found, that I had been mistaken in that respect; and that they were not perfect spheres, each of them having a kind of crease, chink, or indenting, like that which we see in the grains of Wheat, which had at first escaped my notice, partly from the extreme minuteness of the particles themselves, and partly from their different positions with respect to the eye.

Upon viewing these mealy particles, and the indentings in them I have mentioned, I began, not without wonder, thus to reason with myself. Certainly these particles of meal were not composed by a concretion or collection of still smaller particles, placed side by side, as is observed in some liquors, such as wine and beer, whose particles coagulate, and grow together in masses, which, in the former we call dregs, and, in the latter tartar; but the particles of meal must be formed

in another manner, that is, not by coagulation, but by growth. And the membranes which inclose them in cells, must be provided with so many veins or vessels, that every particle of meal may have its separate vein, whence it derives its substance and increase, in like manner as the eggs of fishes are nourished by a ligament or vessel, which is observed not only in the larger fish, but in those very minute eggs which are seen in vast numbers on shrimps. Now, if the particles of meal, which, though not strictly spherical, may yet be termed globules, had not acquired their growth in that manner, it should seem that they could not obtain that globular figure.

When we consider the transparency of every one of these globules of meal, we may well exclaim, How wonderful is this formation, and how closely compacted must be the smallest particles of which each globule is composed, to give it that transparency!

I next proceeded to examine, whether these particles of meal might not be globules, inclosed in a certain thin membrane, as we see is the case with all seeds; but I cannot be confident, that I ever did bring this to my ocular demonstration. I then broke the globules in pieces, and imagined that I saw smaller ones inclosed in them, but herein I found myself mistaken, for, those globules which I saw scattered among the pieces, were some of the very smallest mealy globules, collected in small parcels.

I then used my utmost endeavours, to discover the internal hidden make of the globules of meal, wherein, at length, to my great satisfaction, I succeeded. I placed some of them on a clean glass, and mixed them with a very small drop of water: when they were by this means separated, I poured on them two more drops of water, and brought the glass so near to the fire, that in the space of a minute, the water was all evaporated. Then, bringing them before the microscope, I perceived, that their globular form was changed into flat shapes, of different sizes, according to the different magnitudes of the

globules themselves. Many of them had a little rising in the middle, which I judged to be that part, through which they had received their growth and increase.

This convinced me, that the globules of meal in Wheat, are covered with a skin or shell, in like manner as the Wheat itself, for, by the compression and flattening of the figures in the above experiment, they would have been dissolved or separated, had they not been confined by some such covering. I then concluded, that the chinks, creases, or indentings I have noted in these globules, were in those parts where their skins had a kind of seam or joining, so that when warmed and moistened, their skins had burst open at those places, and the globules subsided into a flat shape, as before mentioned.

From this observation, I was induced to examine the grains of Wheat themselves, in order to investigate, how, and for what purpose they were formed with those indentings, chinks, or creases.

For this purpose, I cut pieces off the grains, by a transverse section, and examined those pieces by the microscope, when I found, that the shell or husk takes its course into the middle of the grain, and, on each side, returns in a curve or bending to the chink, by which means, the husk, when the grain swells upon being moistened, can expand itself into a greater space.

Hereupon I was led to consider, that, whereas fowls, turkies, partridges, pigeons, and other birds who feed on corn, cannot with their bills, break or grind the grains of Wheat, Rye, and Barley, but take them into their stomachs entire, where, by reason of the hardness of the husks, they cannot be broken; seeing this, I say, I considered, that these kinds of grain must have been so contrived and formed by the all-wise Creator, that, without the husks being broken in pieces and digested, their contents may be dissolved: which is thus performed, namely, that by the moisture and heat in the stomachs of

those animals, the outward husks, or shells, may be expanded and burst open, and the meal which they contain, having by this means a passage opened to quit its covering, may be dissolved, digested, and converted into nutriment.

To investigate this more fully, I took a glass tube, about the size of a finger, and closed at one end; into this I put some grains of Wheat and Barley, with a sufficient quantity of water, and then applied so much heat to it, as, in a short time, made the water boil. Then, upon examining the Wheat and Barley, I observed, that their husks, which before, had been as it were closely folded or closed together, were not now, broken or torn asunder, but, in the places where the grains had been contracted and turned inwards, the parts had now receded either way, causing the husk to gape open, so that, in some of the grains, a part of the meal was visible, and in others the whole contents were laid open. Some of the grains of Wheat, however, I observed, which had swelled to three times their original size, the husks remaining entire.

After this, I examined the dung of some hens, which, in the time of a deep snow, were kept shut up in a coop, and fed with nothing but barley, which, it is well known, they swallow whole. And, in the dung of these fowls, I was much surprised to find nothing observable, except a great number of pieces of the husks of barley; and I was at a loss to comprehend, how so great a quantity of meal as those husks had contained, could have entered into the bodies of these fowls, considering that they were all full grown.

Farther, I inspected the dung of many sparrows, in which I found a great number of very small hairs, closely compacted together, in a kind of regular order; together with many fragments of the husks of Wheat and Barley. I at first wondered what these hairs might be, till I recollected the hairy or reed-like parts at the extremities of the grains of corn, which I have before described, and found these to be

the same, for, in them I could perceive a kind of streak or hollow, which is observable on those hairs. These sparrows, I understood, during this season, when the ground was every where covered with snow, sought their food in the corn market, where they picked up the grains which, in handling and viewing the corn, had fallen to the ground.

In order to exhibit to the eye, the manner in which the husks of Wheat are folded or closed together, I caused a drawing to be made from the microscope, of a piece cut from the grain transversely; but first, to shew the position of the chink or indenting, I ordered the limner to draw a figure of the entire grain, in its natural size. This is shewn at *fig. 14*, wherein the fissure, chink, or indenting, is denoted by the letters N O. The line P Q, indicates the part from which, with a very sharp knife, I cut several slices.

Fig. 15, A B C D E, represents a part or slice of the husk of Wheat, inclosing the meal, cut off as above mentioned, and viewed through the microscope. A, is the part near that place in the grain, where the young plant is situated. G H F K I, are the two bendings inwards of the husk, in a kind of circular course, the intent of which formation doubtless is, that, when the grain swells upon being moistened, the husk may expand itself, and still preserve the meal in its place: and by inspection of the part F, it will be seen, that the husk is not closely united where the two bendings or flexures meet, to the end, that when the meal expands itself still more, the two sides of the husk may recede from each other, and produce an opening at that place.

I have already described the size of the globules of meal, by comparison with larger and smaller grains of sand. I also caused some of these globules to be drawn, as seen through a microscope of very great magnifying power; first, to shew more distinctly that they are formed with a chink or crevice on them, next to exhibit to view the

smaller globules, mixed with the larger, and finally, how the chink or crevice appears on them. These are shewn at *fig. 16*, LMNOP Q R.

I have frequently repeated the experiment of placing a portion of these globules of meal, no larger than a grain of sand, upon a clean glass; and, after pouring a drop of water on them, brought it to the fire. After the water and globules were heated, and the moisture was evaporated, the globules assumed a flat shape, very like that of cakes, which is represented in *fig. 17*, STV W. Most of these had a little rising in the middle, being the place, as I before mentioned, where, in my judgment, they were supplied with juices in their growth. And I have often seen the very smallest of the globules undergo the same alteration in their shape as the larger ones. In these observations I found a portion of meal, no larger than a grain of sand, mixed with a small drop of water, fully sufficient to exhibit the change of shape before noted; for, if more of the meal is used, the particles lie so confusedly heaped on one another, that they cannot be distinctly seen, and, it is scarcely to be conceived, that a portion of meal, no larger than a grain of sand, should consist of so many particles as are pictured in *fig. 17*.

I have often examined a small piece of bread, taken from a loaf made of fine flour, after the husk or bran had been taken from it. The particles of meal in this small piece of bread, appeared very much like those represented in *fig. 17*, with this difference only, that the particles in the bread, lay much more irregularly, and appeared more mis-shapen, with ragged points and risings; a true representation of all which is to be seen at *fig. 18*, ABCDE.



(881)
ADDITION, BY THE TRANSLATOR.

WHOEVER peruses Mr. Leeuwenhoek's Works, will find displayed in them much sound philosophical knowledge, of which some instances appear in the preceding Essay. These I shall quote, in order to explain the parts in them, which may appear difficult to some of my readers. In page 171, the author tells us, that the substance inclosing the young plants of Wheat, appears of a different colour from the mealy part of the grain, by reason that the globules which compose it are not, singly, so pellucid, and therefore do not, altogether, appear so white, as the meal; and in p. 179 he reflects, with admiration, how closely compacted must be the smallest component particles of the globules of meal, to give them that transparency. To those, who are not conversant in optics, it may appear strange, that the most transparent bodies have the smallest pores, and, that a collection of small transparent globules should altogether exhibit a white colour, but this is according to the established doctrine of light and colours, of which Mr. Leeuwenhoek appears to have been fully informed.

As to the first, Sir Isaac Newton has shewn, that it is not the largeness of the pores of bodies which makes them transparent, but the equal density or continuity of their parts; which, he says, appears from hence, that all opaque bodies immediately begin to be transparent, when their pores become filled with a substance of equal or almost equal density, with their parts: thus paper, dipped in water or oil, linen cloth steeped in oil or vinegar; and other substances, soaked in such fluids as will intimately pervade their little pores, become more transparent than before.

As to the second, white being a composition of all colours, a collection of transparent globules, which, from their surfaces reflect the light in all directions, will produce whiteness by that reflection. This is seen in the froth on liquids, and particularly soap-suds, which is nothing but a composition of minute globules of water, made tenacious by the soap.

Of the Cocoa Tree, and its Fruit, commonly called the Cocoa-nut.

I HAVE said, that straws, reeds, and many other stalks of plants, were formed of none other than perpendicular vessels, whereas the stems or bodies of all trees growing in our climate, at least as far as I have ever understood, are likewise provided with horizontal vessels; the use of such last mentioned vessels being, in my judgment, to convey the nutritive juices to the exterior parts of the tree. Now these horizontal vessels impart such strength and firmness to the timber or trunk, that the most spreading trees are enabled to resist the violence of the wind.

But straws, reeds, and other stalks which are destitute of horizontal vessels, require some other means of support; for, if all the vessels, from the earth up to the summit of the stalk, were disposed only in uninterrupted parallel lines, the stalks would be so weak and flexible, that they could neither resist the wind, nor be able even to bear the weight of their own fruit. Therefore, these kinds of stalks, are strengthened by a sort of joints or knots, at intervals, which prevent the over much bending of the stalk; and the joints are placed at such distances that the spaces between each will allow the bending, only so much as to recover itself.

What has been said of the joints in stalks growing in these regions, I consider as applicable to some sorts of trees in the Indies; and, upon seeing some of those Indian trees described in drawings, I immediately concluded, that the Cocoa Tree was of the number.

After several endeavours to obtain a specimen of this tree, I at length

procured from a certain sea captain, a piece of one, about a foot long, and ten inches in diameter. The bark of this wood was found, but the wood itself so decayed, that it crumbled into powder under the fingers, excepting only a very small part. The capillary or hairy parts which run lengthwise on the inside of the bark, were tolerably found, but they separated from each other, as easily as if they had never been firmly united, which made me suspect, that, if there ever had been any other parts to connect them, they were decayed.

I perceived that these capillary or hairy parts, grew out of the bark, and that many of them were divided into two; and I also perceived in each of these capillaments many vessels. Among these capillary parts were others, some firm and solid, others in the nature of vessels, but the greater part of them much decayed.

These capillary parts, were covered by the external solid bark, which bark was, in some few places, thicker than in others, but, at the knots or joints, the bark was remarkably thick and solid.

This bark, cut transversely, I examined by the microscope, and found it chiefly to consist of roundish threads, about the thickness of an hair, and these again composed of oblong filaments, hollowed on the insides. Many of these latter did not take a straight, perpendicular course, but turned inwards towards the body of the tree. Farther, I observed, intermixed among them, a kind of substance, consisting of roundish globules, connected in a sort of regular order. These parts, composing the external substance of the tree, were so closely united together, that it might be thought the tree had not any bark on it. From all these observations, I was led to conclude, that this tree receives its growth and increase from the bark alone. And I perceived certain roundish parts, which seemed to issue in a right line from the bark inwards, as if they were designed for no other use, than to convey the nutritive juices in that direction.

If, however, we could be furnished with a piece of this tree, cut while alive and growing, our observations might be much more accurate. And, indeed, I was not without suspicion that this piece of wood had been cut from a dead tree, though one of the seamen assured me, that the decay which I have before mentioned, happened to it on board the ship.

In order to place before the reader's eye the form of the joints knots, or bands, whereby the body of the Cocoa-tree is strengthened, and which as it were, surround it throughout with a sort of girdle, I caused a drawing to be made of this piece of wood, on a contracted scale; from which drawing will be seen, how firmly those trees, which have no horizontal vessels, are strengthened by these kind of bands, surrounding them in an oblique direction.

In Plate VII. *fig. 1*, A B C D E F G H I K L M, represent this wood drawn smaller than the natural size. C M, C L, D L, E K, F K, F I, indicate the position and course of the knots or bands, that is, that they do not go in a straight line round the tree, but sometimes approach to, and sometimes recede from, each other, which approach and receding are shown at K L. And, this oblique course of the knots, bands, or cinctures, contributes more to the strength of the tree, than if they encircled it in the form of hoops.

By cutting and examining this wood, in the manner I have described, I fully satisfied myself in the particular wherein I wished to be ascertained, namely, that the Cocoa Tree has no horizontal vessels. And there is moreover a circumstance to be noted in these kinds of trees, that they have no branches except at the very tops, and therefore, are not so strongly acted upon by the force of the wind. Nor are the branches which they have, perennial, but they every year fall off, and are replaced by fresh branches, which grow on the tree at the same time with the fruit.

I also cut transversely a piece of the wood, in a part where it was

found, in order to shew, as accurately as possible, the make and texture of this wood, when viewed by the microscope.

Fig. 2, O P Q R, represents a very small particle of the Cocoa wood, cut transversely, and magnified, wherein are to be seen six of the larger of the perpendicular vessels, two of which, surrounded by a great number of smaller vessels, are to be seen at T T. Of these larger and smaller vessels, the capillary or hairy parts I have mentioned, and which are very tough and strong, are composed. But these vessels do not all ascend in an exact perpendicular direction, but creep upwards in a kind of oblique course, one among another, by which position they contribute to the strength of the tree. And when one of these vessels or threads divides itself, each divided part, though it presents the figure of a smaller filament, is yet in truth a perfect vessel. These smaller vessels, intermixed with the larger ones, I have caused to be represented in the drawing.

These larger vessels seem connected together by a kind of vesicles, which, I imagine, while the tree is alive and flourishing, are filled with some kind of liquid. These vesicles are not disposed in any orderly or proportionate manner, but in some places they may be seen heaped together to the number of five and twenty, and in other places, between two capillaments, will be found only a single vesicle.

Such of these capillaments as are next to the bark of the tree, are exceeding small, in comparison of those nearer the middle; and, to exhibit them to the reader, I cut off a piece of the wood next to the bark, and caused it to be drawn from the microscope, which drawing is copied at *fig. 3*, A B C D. In this figure, A D is an innermost bark next the wood, being a very thin skin, and the capillaments next to it are the smallest of all, whereas those more inwards, grow larger and larger. But, though these innermost capillaments are the largest, they are still composed of those exquisitely

thin and hollow filaments I have mentioned, the hollows or cavities in which I have caused to be represented by a sort of points or dots. The black shade in this figure, denotes minute vessels surrounding the others, which by reason of their exceeding smallness could not be represented in the drawing.

These vesicles, which I have mentioned to adhere to the capillaments, as they appear, when cut by a straight section, are shewn at *fig. 4*, E F G H. In these vesicles there appeared some small particles, concerning which, however, I could not pronounce any thing with certainty.

After I had made the preceding observations, I received from a friend who observed how desirous I was to investigate the nature of the Cocoa wood, a piece of that wood which he had procured from the island of Curaçoa. This was seven inches in diameter, and about four inches long: in the middle, it was composed of the before mentioned larger capillary parts, but, on the outside, and about an inch from the surface, it was so hard, that in attempting to split it, I broke a steel wedge in pieces, and I do not remember ever to have met with so hard a wood.

Between the bark and the solid part of this wood, I saw some capillary parts creeping along, and which were of the same nature as those pictured in *fig. 1*, between G and N, and these capillaments, I was informed, are made use of to be twisted into ropes and cables.

I observed, that wherever the knots or bands in the bark approached each other, as at F K, there the capillaments grew out of the bark: sometimes I observed one or two branches rise out of one of these capillaments, and these again subdivide into smaller ones, hollow within, and which capillaments I judged might in time unite and form vessels of the size pictured in *fig. 2*, at T T. And if so, it follows that the Cocoa tree receives the addition to its bulk from the

bark, contrary to what we see in the trees of this country, the bark of which receives its increase from the wood.

I also cut this wood from Curaçoa transversely, and examining it by the microscope, I found it to agree in all respects with that represented in *fig. 2*, with this difference only, that where this wood was harder than the former, there the capillaments were smaller, and also exceedingly tough.

But as the vesicles in the former wood, which are represented at *fig. 4*, EFGH, were in this latter much harder, and also smaller than the former, I cut some of them by a straight section, and caused a very small particle of them, when magnified, to be drawn from the microscope, which is to be seen in *fig. 5*, at 3LM2. These vesicles, I perceived were of a more firm and solid texture, than those in the other piece of wood, and they had in their centers a black spot, which was a sign that they had had a cavity in them: some of these vesicles I cut in such thin slices that they appeared transparent.

While I was busied in this part of my investigation, I happened to cut one of the ascending vessels, which in *fig. 2*, is denoted by T, but which here is shewn between IK 3 2 N. And, though the smaller vessels surrounding it, could not, by reason of their minuteness, be otherwise expressed, than by straight lines, yet this larger vessel plainly appeared to be formed of a kind of annular parts, running round each other in a sort of spiral form. And, though I had observed this formation of the vessels in many other sorts of wood, yet I could not till now, venture to say, that these vessels were formed in that manner, because I had hitherto lost my time and labour in endeavouring to dissect them accurately. But now in this object, where the vessel spread or opened itself a little, at the place marked N, I plainly saw the spiral formation, which discovery gave me great pleasure.

I proceeded still farther in the examination of this larger vessel, and I found it to be composed of, at least, five smaller ones, which were placed in regular order, beside each other, and each severally formed in the spiral manner I have mentioned. All these are shewn in *fig. 6*, O P, and in the same figure, at P Q, is to be seen the part which I before mentioned having seen, as described in *fig. 5*, at N.

This circuitous figure of the vessels, may be exactly compared to a brass wire, twisted round a small rod, and the same kind of formation I have frequently, as I have before mentioned, seen in other woods. And even in a straw I once observed, by the microscope, one of its larger vessels to be formed, much in the same manner as this I have described at O P. And, when we consider the subject, we cannot, in my humble opinion, conceive any form so suitable for those vessels to raise the juices upwards.

The same gentleman from whom I received the last mentioned piece of Cocoa wood, sent me also two Cocoa nuts, inclosed in their several shells or coverings. From one of these I cut so much of the outer covering, as to exhibit the inner shell to view; and I caused a drawing to be made of both, on a contracted scale, which is to be seen at *fig. 7*, A B C D. The diameter of this external case or covering was nearly five inches and three quarters, measured by the scale B D, which is five inches long.

This external husk or shell so firmly adhered to the inner one, being connected to it by multitudes of vessels, that I found it a work of considerable labour, to tear it off. The inner shell was four inches in diameter, and, having cleared it from all the vessels adhering to it, I replaced it in the half of the case or husk, as is to be seen in the drawing.

I have often been told, that the filaments of which this external husk or bark consists, are of such a length that they are twisted into cables, and also wove into sail-cloth. I proceeded, therefore, to exa-

mine the texture of this husk or bark, when I found, that not a tenth part of it consisted of those filaments, but that, from them proceeded a certain substance, like a collection of vesicles, which vesicles, while the fruit was living on the tree, had been filled with juices, in like manner as those parts which, collected in great numbers, from the substance of the pear called the Sugar pear, do proceed from the veins or vessels in that pear.

To convey a true idea of the formation of this external coat, husk, or covering, of the Cocoa-nut, I caused a drawing to be made from the microscope of a very small piece of it, as is to be seen in *fig. 8*, M N O P Q. Here, N P Q denote the capillaments, which may more properly be called vessels; they are each inclosed in a larger one, which larger one is composed of numbers of minute vessels.

It is well known, that all fruits, and even the smallest leaves, are covered with a skin, which, that it may prevent the exhalation of the juices, is of a very close texture. This external coat or husk of the Cocoa-nut has that kind of skin, which, as it appears through the microscope, is exhibited in *fig. 9*, A B C D E F G H, where are shewn as exactly as may be, the vessels running along this skin, and connected with the internal part of the husk, as for example, as B D E, A E, and H G. A branch proceeding from the vessel B E, is represented at C D.

In the shell of the nut, pictured at *fig. 7*, there are three parts somewhat resembling eyes, two of which point towards each other, the third contains the young plant, which, when the kernel begins to vegetate, shoots out through that cavity. And this young plant in its vegetation receives nourishment from the kernel, through these perforations I have called eyes, until it is able to draw its nourishment from the earth, and this, without there being a necessity for the shell of the nut to break or open. The vegetation of the

chelnut is performed in the same way, contrary to what is observed in the feeds of nuts, plumbs, and the like, the shells of which, as the vegetation of the kernel advances, divide and open themselves.

Moreover, I cut off several pieces from the hard shell of the Coconut, some of them longitudinally, some transversely, in order to shew the texture of it, as seen by the microscope. This is represented at *fig. 10*, IKLMN, in the inner part of which is a vein or vessel dividing itself into many smaller ones.

I next proceeded to examine a thin membrane or skin, which lines the inside of this hard shell. An incredible number of vessels which may be seen by the naked eye, are dispersed through this membrane; the hard shell is of a dark colour, verging towards a black, and the membrane of a faint ash colour. I have often placed pieces of this membrane before the microscope, and could not, without admiration, behold the almost incredible number of small oblong parts therein, which were heaped one on another, in such various manners that I could not conjecture for what use they were designed; but they all consisted of spiral parts, such as are described in *fig. 6*, at O P. These parts were so exquisitely slender, that upon comparing them with a vein taken from the breast of a flea, which I had standing before a microscope, I found that the vein (which was also of a spiral form) was about four times as large as these component parts of the membrane, and I could not sufficiently wonder at the multitude of those spiral parts.

I have also often placed before the microscope, those capillaments which in breaking the shell I found adhering to it by one of their extremities, merely for the pleasure of contemplating the object; for, a capillament no larger than an hair, would be seen to consist of twenty filaments, the smallest of which I judged to be less than the thread spun by the silk worm. So that, if we would compute the whole

number of these filaments in a single nut, we must not reckon them by thousands, but by hundreds of thousands.

That which is the kernel of this nut, and is commonly called the Cocoa-nut, is a very white substance, about half an inch thick, closely joined to the whole interior part of the shell; the remainder of the cavity contains a watery juice, which is what I never observed in any other seed, when come to maturity. For nuts and chesnuts are entirely composed of solid parts, which we call the kernel, though before they come to maturity the matter inclosed in them is no more than a watery and slimy substance.

Upon this head, I reasoned with myself; that before the inward substance of the Cocoa-nut is full grown and ripe, the shell becomes harder than those of any fruit known in the northern climates; and I concluded that when the shell is grown perfectly hard, it cannot be afterwards increased in size, nor can the kernel it contains receive any addition to its substance: and therefore, that part of the nutritive juice which is of a watery nature, and cannot be converted into kernel, must remain in the center of the nut.

I afterwards fell into conversation with two masters of ships, who had visited both the East and West Indies, and had been often employed in collecting Cocoa-nuts. They informed me, that when the shells of the nuts were so soft that they could be cut with a knife, there was nothing to be found in them except a lymph, or thin liquor, of a very pleasant taste, which information confirmed me in the opinion I have before related.

At another time, upon a different investigation of the Cocoa-nut, I pressed from the pulp or white substance of it, such a quantity of oil as fixed me in astonishment.

After this, upon opening a Cocoa-nut which I had kept for the space of seven months in my cabinet, I observed those three soft places in the shell which are called eyes, and from one of which the

young plant shoots forth, to be covered, and, as it were, sealed up, with a substance like rosin or pitch.

To give a more perfect idea of the nature of the Cocoa-nut or kernel, after I had bored the shell near the place where those parts I have likened to eyes are situated, and poured out the juice contained in the cavity, I broke away the shell so far as was sufficient to shew the inside of the nut, that it might be expressed in a drawing.

Fig. 11, OPQR, represents the Cocoa-nut or kernel as it appears, inclosed in the shell, which shell is denoted by PQR. At P R, are some of those capillaments, which in great numbers, are found united to the shell, and, as they are in fact, no other than vessels destined to convey the nutritive juices, they penetrate into the interior part of the shell, and there impart nourishment to the fruit. Farther, many very small vessels take their course through the hard shell, and these, as I found by the microscope, were composed of other vessels incredibly slender, the smallest of which were of the spiral formation described in *fig. 6*, OP.

STV, denote the nut itself, properly so called. WXY is a cavity within it, which contains the sap or juice I have mentioned, which is very pleasant to the taste, and of a nourishing quality. A drop of this juice I put into a very clean glass, in order, when the watery parts of it were exhaled, to examine the remainder, and therein I did not find any saline particles, but it had the appearance of a syrup, which did not evaporate, being more of a fixed nature.

This kernel is connected with the hard shell by infinite numbers of vessels, and on the side next the shell is also covered with a thin skin, through which multitudes of vessels take their course; they are of the same spiral figure as before mentioned, and lye close together, and they are not much thicker than the hair of a man's

beard. Whence it appears that the kernel is formed and nourished from these very slender vessels.

Upon examining this nut or kernel by the microscope, I found that its substance is not, like other seeds, inclosed in small membranes; but consists of multitudes of minute tubes, which take their rise from the hard shell, and reach to the cavity, within the kernel, where the juice I have mentioned is collected. They are not all of an equal size, nor are they of a round figure, but rather of six sides, which shape is well adapted to permit their lying close together and in regular order. Some of these are turgid with a certain substance, which in part evaporates; others of them contain globules which I judged to be chiefly filled with an oil.

These small tubes, which in *fig. 11* are to be seen at *W*, I cut transversely, and caused a drawing to be made of a very small portion, as viewed by the microscope, which in *fig. 12* is expressed by *ABCD*: the small points, or dots in this figure, denote some very small particles, which I observed in these tubes.

Moreover, I caused a drawing to be made of that part of the nut or kernel, where I judged the young plant to be situated, in the shape it exhibits when seen by the eye alone, without the microscope. This occupies but a very small part of the kernel, and is situated in a part where its substance is thinnest. A drawing of this, of the natural size, is to be seen at *fig. 13*, *ABCDEF*, and *HEG* is the part which in my judgment contains the entire young plant.

From this part I cut some very thin slices at that end of it which in *fig. 13* is nearest to the letter *E*. For I was desirous to examine whether any thing would there be found bearing any similitude or resemblance in figure to the future stem of the tree. Some of these slices I placed before the microscope, and caused a very small portion thereof to be drawn, that it might not take up too much space in the paper. This is represented in *fig. 14*, at *EFGHI*. In this

figure *IEF* denote the skin or covering, inclosing what I take to be the plant. The remainder of the figure represents ascending vessels, and which, as far as I could discover, were filled with an oil. Those parts which appear like larger vessels, and are indicated by *KKK*, were shining and transparent, and were composed of other vessels, so small as to exceed all belief.

Upon cutting this part marked *HEG*, not far from the end, next *H*, I was astonished to find that this was not, wholly, the young plant, but chiefly its case or inclosure, the young plant itself, which was contained in it, being not much larger than a grain of sand. One of the pieces thus cut off I placed before the microscope, and delivered it to the limner, directing him to make a drawing of the object which presented itself to him, as nearly as it was possible for his art to imitate it. This slice, which had been cut lengthwise, thus depicted, is shewn at *fig. 15, IKLM*.

I took great pains to examine many Cocoa-nuts before I could be certain that what in *fig. 15*, is marked *IKM*, was really that part of the young plant which would penetrate downwards into the earth, and become the root, and that what is described at *KLM* was that part which would grow upwards into a tree; but I am now satisfied that this is the case, and that the parts last mentioned are the leaves, which in this young plant are already formed.

I many times endeavoured to separate these young plants from the integuments inclosing them, but always in vain; because that part which in *fig. 15* is denoted by *IKM*, firmly adhered to those integuments. All I could do therefore, was, to cut the young plants in pieces by a longitudinal section; in doing which, however, it often happened, that the object presented three or four shapes to the view, by reason that I had sometimes cut the plant directly through the middle, and sometimes on one or the other side. To set this also before the reader, I have given two drawings of the pieces so cut,

omitting only the integuments or circumjacent parts inclosing them.

The first is, of a plant which I had, as I believe, cut exactly through the middle, and it is shewn at *fig. 16*, NOPQ. Here, NOQ, is the part which would become the root, and OPQ, that which would grow upwards into a tree. And, in this young plant, are plainly to be seen the leaves with which it is naturally furnished.

The other, is of a plant which I judged, had not been cut through the middle; for which reason it did not appear so large as the former, nor were the leaves equally conspicuous. This is exhibited at *fig. 17*, RSTABZ. The place of the future root in this plant is marked by RSZ, and that of the stem by SABZ.

Although I frequently repeated these experiments, it was only twice that I could observe the upper part or future stem of the plant, in drying, separate itself from the circumjacent parts. This separation I have caused to be expressed in the same *fig. 17*, at SABZ, and at TY.

I have generally observed, that the young plant, in that part which, in *fig. 13*, is noted by EHG, occupied not more than one half of the space there represented, and lay near the part marked H. But, at one time, I saw the young plant occupy only a third part of the space; whence it follows, that such space or cavity was nine times as large as the plant it contained.

Farther, I twice observed the young plant to lie, not precisely in the middle, but rather on one side of the before mentioned cavity, whence I concluded, that it had begun to vegetate while in that part, for I saw that the circumjacent parts had in that place begun to separate from each other, so that, had the vegetation continued, the plant would have found its way out of the shell. This separation of the parts is represented in *fig. 17*, at AWB.

Moreover, I thought it right to give some representation of those

extended parts which furround the upper part of the young plant, or, more properly speaking, the whole of that plant.

Let us suppose then, that I have cut off a small slice of that part which in *fig. 13* is pictured between G and H, and, that in *fig. 17*, a small part of the circumference of this slice, and of the skin inclosing it, are described at VWX. By T, and by VWXY, that substance is expressed, in which the young plant, or rather the upper part of it, is as it were, inclosed and wrapped up. The parts of this substance, exhibit the appearance of small vessels, which lie disposed in such straight lines, that they naturally seem designed to convey nourishment to the plant. But, in the part pictured at H, in *fig. 13*, and where there will be found a kind of swelling, these vessels are stretched out to such a degree of fineness, that none of the parts within them can be distinguished without the greatest attention.

As the kernels of Almonds, Walnuts, Peaches, and Plumbs, which are inclosed in shells, are denominated the seeds of their respective trees, so the Cocoa-nut, or fruit of the Cocoa tree, ought to be reckoned among the seeds of trees. In the seeds, however, of the trees I have first mentioned, whose shells are all formed with a seam or joining, those shells, when the vegetation proceeds, and the kernel swells, open at the seam, and the young plant in the kernel, having more space afforded it, can expand in its growth, and strike its root into the earth. But the shell of the Cocoa-nut has not any seam or joining, being of an equal strength and thickness throughout, therefore its vegetation must be provided for in a different manner; and this I conclude to be as follows. The moisture in the Cocoa-nut being inclosed and confined on every side, when it begins to be agitated by that intestine motion, produced by heat, must necessarily expand itself with great violence, and, by that expansion, the part which contains in it the young plant, is by degrees, as the

plant increases in size, driven out of the shell through the aperture before noted.

Those, who have lived many years in India, affirm, that there is no tree so beneficial, or which produces so many conveniences to mankind, as the Cocoa; and that it is converted to upwards of sixty different uses by man. The nut not only supplies him with food and drink, but from the nut is also extracted a liquor not much unlike the spirit distilled from barley, and from the same nut vinegar is made. The tree itself furnishes masts for smaller vessels, and the capillaments or filaments which surround the nut are partly wove into sail-cloth, and partly twisted into cables, which are used even for large ships. If the trunk of the tree be pierced with a small incision, there will flow from the wound, every day, a quart of excellent liquor, and this operation may be performed twice in the year; the trees, however, which are thus treated, are deprived of their fertility for that year.

If we compare the size of the Cocoa-nut, with the very small plant it contains, we may safely say, that the nut is above one hundred thousand times larger than the plant, and we may thence conclude that this nut, and the pleasant liquor it contains, are destined by nature, or which is the same, by Providence, for the use of man, and to supply many of his wants.



ON HOPS.

OF the Hops which grow in the Low Countries, those from Liege are preferred to ours here in Holland, and, I doubt not, with reason, because the territory of Liege is one degree and an half more to the southward than Holland, consequently the Hops will sooner come to maturity there; besides, in the lands about Liege the soil is deeper than ours. The following are the observations I have made upon this plant.

I examined by the microscope, those leaves of the Hop, which compose the pod, or case, containing the seed; which leaves, being remarkably thin, afforded me a very pleasant object to behold, the veins or vessels scattering themselves in all directions about the leaves, and, in some places, uniting again. Some of these vessels, I perceived to be filled with a red substance, others were of a spiral figure, resembling those veins which I have observed in the leaves of tea.

Many of these leaves, I observed to have a small seed adhering to them, at that part, where the footstalk of the leaf had been joined. And, indeed, I think, that these small leaves thus bearing the seed, are so formed, that each shall produce one seed, but, it is my opinion, that the seeds, when the leaves do not grow to perfect maturity, cannot ripen.

Many of the seeds I dissected, and found nothing in them, except the young plant, which was chiefly composed of the part that would in time become the root. There were, however, two leaves formed

in the plant, but nothing else remarkable, except an immense number of small vessels or veins, dispersed throughout the beginning root.

All these feed pods or leaves, chiefly in that part through which they had received their growth and increase, were covered with exceeding minute globules, glittering with a beautiful yellow, like gold. As far as my eye was able to judge, these globules were in diameter about equal to the thickness of an hair of one's beard, but some of them not so large. I do not consider them to be the fruit of the Hop, but, some matter or substance, issuing from the plant, such, for example, as if it was turgid with a superabundant quantity of juices, or, that the heat of the sun might some days be remarkably intense, and that by the very great quantity of juices, or their extraordinary expansion, they had burst through the vessels. Many of them I broke, and I did not think that they were covered with any shell or coat, farther than that their external surface being hardened in drying, exhibited something of that appearance. They contained only a limpid oil, of a glittering yellow, and also other globules, much smaller, but more solid, and which with the oil, filled up the cavity of those first mentioned globules.

This appearance of globules, on the surface of the leaves, I think very similar to what I observed some years ago, at a house where I was upon a visit; the back part of which house, was covered with a vine, facing the southern sun. The young shoots of this vine, I observed to be, in many places, covered with transparent globules, and I judged them to have arisen from the superabundant juices, which, by the heat of the sun, had been brought forth in such plenty, that there was not a passage for them through the narrow vessels of the branches, so that they might be absorbed by the grapes. And the warmth on this vine seemed to me, to be farther augmented from this circumstance, that the ground which covered the root, was very curiously paved with small different-coloured pebbles, without an

herb or blade of grafs appearing between them. And the juice, thus expelled from the branches, was inspissated or thickened on their surfaces into globules.

Upon examining the globules on the Hops by the microscope, I found, that the part which might be called their coat or shell, was not smooth, but rough, and in wrinkles, occasioned, as I concluded, by this, that the juice which issued from the plant, and formed itself into globules, had, in part evaporated, whereby the outer surface or skin of those globules, contracted into wrinkles.

These yellow globules, when broken, and put into a clean glass, I suffered to stand in the glass for some days, and then applied myself to examine the oil. I found that great part of this oil, had collected itself into thin oblong particles, and, in such numbers, that I could not but silently wonder at the sight. Where this oily substance lay much dispersed, there, the oblong particles I have mentioned, did not exceed in length the diameter of a very fine thread of wool, but, where the oil was collected in larger quantities, they were four times that size. In some places, I observed oblong particles, with twelve points, issuing, as it were, from a center, with one of their ends terminating in a point, the others, blunt or obtuse.

Now, we may lay it down for a certain truth, that those pellucid and oblong particles, which I have mentioned to be intermixed with the oil, although, by their minuteness, they escape our sight, are really a species of salts, and that the bitterness which Hops impart to beer, is produced by those salts. And we may also be assured, that these minute salts, although they may be a thousand times less than what can be seen by the microscope, do yet, agree in shape and figure, with the larger salts of the same species compounded of them, in like manner as we observe in common salt, in nitre, or salt petre, and in many other salts. The same may be observed, in that kind of sugar called sugar-candy; for, upon this becoming damp, on being

exposed to a moist atmosphere, when it afterwards dried, I have heard women complain of its having lost its bright colour. Upon examining into the reason of this, I found, that the surface had been in part dissolved by the moist air, and when, in drying by the fire, it again became hard, an incredible multitude of small particles, very many of which agreed in shape with the larger parts, had collected upon the surface, and this collection of minute particles, clouded the brightness of the sugar-candy.

But, to return to the salts in Hops ; how will those philosophers get over the difficulty, who obstinately contend, that bitterness is caused by a sort of minute hooks in the salts, which by their punctures produce that taste we call bitterness ?

I have often laid a single leaf of the Hop, such as I have described it, upon my tongue, and held it there the space of half a minute ; for I was desirous to try the experiment, whether such a single leaf, which is frequently covered with the yellow globules I have described, could excite a sense of bitterness. And, it is not without wonder, I declare, that such a single leaf, upon being strongly compressed between the tongue and the palate, spread all over my tongue a very bitter taste, and indeed, much stronger than I expected.

Not content with these observations, I placed a parcel of these oily globules, some of them pounded or bruised, some of them entire, in two separate glasses, and, with all the attention I was able, I examined them by the microscope, but I did not find any particular kind of particles in them.

I then placed the glasses in my cabinet, and, that no kind of filth or dirt might become mixed with the oil, I covered them with paper. After twenty-four hours had elapsed, I examined them very attentively, and, in some few places, I perceived some of those oblong particles I have before mentioned, which were very small and thin, and after twenty-four hours longer time, a much larger portion of such

salts was discoverable. These observations were in the winter, when the weather was not favourable for such enquiries; but, had they been made in a milder season of the year, I doubt not, that the salts would have been formed more speedily, and in greater plenty.

I think it might be worth while, in the summer-time, to examine the flowers and blossoms of various trees, particularly those, of which bees appear the fondest, by which examination it might perhaps be discovered, what kind of substance, if any, and of what qualities or properties, issues from such flowers, and adheres to their surfaces.

At one time, in the month of October, I was informed by a Hop Factor, that the Hops in that year, were of an excellent quality, whereupon I procured some of the seed pods, of that year's growth. Upon examination, I found each of these seed pods to contain thirty or even forty feeds. When I had stripped the feeds of the small leaves or integuments surrounding them, I observed, that the young plants within them contained, in proportion to their size, abundance of oil. I farther noted, what I have already mentioned, that each young plant had two leaves, and these in proportion to the minuteness of the plant, were remarkably long. These leaves lay in each feed compacted and twined together, much like the spiral folds in the shell of a snail; and, when I laid open the folds, I saw within them, still more leaves, but excessively minute, and which indeed, I could not discover in all the feeds. From hence it appears, that the feeds of the Hop differ from most of the larger sort of feeds, and do not contain in them any substance to nourish the young plant, which plant therefore is more perfectly formed than that in the larger feed of the Chestnut.

As to those beautiful globules which I have before mentioned to have observed, those, in this specimen of the Hop, were dried, and rather shrivelled. Having broken them, I put them into a glass, and breathed on them with my warm breath two or three times, where-

upon the oil dissolved into a wonderfully fluid substance. The glass I then placed, where no dust could reach it, and, upon examining it the next day, I saw such a multitude of salts of different magnitudes dispersed about the oil, as it would almost exceed belief to relate. Most of these salts were pointed at each end, but many of them were so minute, that their figure could not be known or judged of, but by reference to the larger ones adjoining to them. In some of my observations on this oil, I found the salts to appear in it, at the expiration of only half an hour after it had been put into the glass, and they increased in number and size every hour, the smaller growing larger, and the oily liquor evaporating; and I found that this specimen of the Hop plant, contained twice as many salts as were in the former one.

I observed one thing which seemed strange to me, namely, that many of those oblong salts which I had said were pointed at both ends, did not extend in a straight line, but were somewhat bent or doubled together; but, whether these salts so bent into a bow-like figure, do, for that reason, excite the motion or sensation in our tongues, which we denominate bitter, I leave to be examined by others.



ON COCHINEAL.

WHEN I first applied myself to investigate the nature of Cochineal, I concurred in the general opinion which then prevailed, that it was the fruit of some tree; and, having at the request of the Honourable Mr. Boyle, further prosecuted the examination, each single piece, or fruit, as I then thought it, appeared to contain one hundred or upwards of what seemed to me to be very small seeds, shaped like eggs, each inclosed in its particular membrane; these objects, however, I could not bring into view, until the Cochineal had lain in water for some hours, and then, the outer skin being taken off, these apparent seeds, which were very soft, presented themselves; many of which were inclosed in the membranes I have mentioned, which seemed to be their natural coats or coverings, and were twice as large as the seeds themselves: the membranes were filled with a watery substance, of a lovely red, but the seeds were of a dark red or tawny colour. The seeds themselves, upon being dissected, appeared to consist of nothing but very minute globules of a red colour.

The remainder of the Cochineal, or that part of it which inclosed all these seeds, was composed of very thin membranes, which were also of a red colour, except that a very small quantity was to be seen, of a certain colourless substance, which, to me, had the appearance of an oil. And to give an idea of the general appearance of the figure of Cochineal, I know not any manner of expressing it, better than by comparison, with a parcel of dried black currants, with their skins and seeds.

regard being nevertheless had to the different sizes of the currants, and the Cochineal. Lastly, when I divided the membranes or feeds of which Cochineal appeared to consist, into as thin portions or particles as I was able, those thin particles, did not, as I may say, exhibit any particular colour.

The preceding observations I communicated by letter to Mr. Boyle, from whom I received an answer, to the following effect: that he had understood from a Governor of Jamaica, that Cochineal was produced from the fruit of the fig-tree, when in a state of decay, at which time, there proceeded from thence, certain maggots or aurelias, which changed into flies; that these flies settling on the trees were there killed by making fires under the trees, the smoke of which caused them to fall down; after which, they were stripped of their heads, the fore parts of their bodies, and their wings, and the remainder preserved for use, so that Cochineal was properly, and in truth, the hinder part, or tail of a fly, and consequently, that my observations were so far correct, that the substances I had seen were really eggs, such as are found in the hinder part of the silk-worm's moth.

To this I replied, that, in my preceding observations, it was impossible for me to judge, that Cochineal was an animal substance, because there was nothing to be seen in it, that resembled an animalcule, and that I had concluded, if it had been an animal, it would have been devoured by those minute animalcules, called mites; and I added, that in consequence of the information communicated by the Hon. Mr. Boyle, in his letter, I had repeated my observations, the result of which as I communicated them to him, is as follows.

On this renewed investigation of the subject, I was fully convinced, that every single grain of Cochineal, was part of an animalcule, from which, not only the head, the fore part of the body, and the wings, had been broken off, but that also the legs, and that part of the body

to which the legs are joined, had been thrown away, so that nothing was left, except the animal's hinder part; and I imagined, that the colourless substance I before mentioned, and which is to be observed in the chinks or creases in every grain, is some preparation, applied to the Cochineal, when it is collected for sale, to defend it from the mites, which otherwise would destroy or devour it.

These creases or rings, in every grain of Cochineal, I imagine are, the articulations or joints, in those kinds of maggots or caterpillars, which afterwards change into a flying insect: And I did not doubt, that, at the proper season, when a similar kind of insects could be found in this country, I should establish that fact, allowing only for the difference in shape and colour between them, and those which constitute Cochineal.

After this, I examined a large parcel of Cochineal, and in it I found several of the shells or coverings of the wings, which shells were of a black colour, with each a red spot in the middle. Many insects are provided with these kinds of shields, shells, or cases, to defend their wings and the hinder parts of their bodies, which are very soft, from injury; and, when they prepare to take their flight, they erect these shields or cases upright, and spread their wings.

In this parcel of Cochineal, I also found among the grains, some fragments of aurelias, which I concluded had been formed from the maggots or caterpillars of this species, and, in one of them was a piece of a maggot, which, in part, seemed to have been devoured by mites.

The children in this country, are accustomed, in the spring time, (when the white nettles, or, as they are commonly called, the blind nettles, are in blossom) to go in search of a species of small flying insects, called by them lady-birds, which, for the most part, are to be found on those nettles. The subject now before me, caused me to turn my thoughts on these insects (though they are smaller than those whose bodies constitute Cochineal) and I employed some chil-

dren, at the proper season, to collect some of them for me; judging that, when stripped of their wings with the cases, and their heads and feet, the remainder would be found to resemble Cochineal.

These lady-birds, as they are called, I killed with the smoke of sulphur, and afterwards dried them; and when I had taken off the red shells or cases which cover the hind parts of their bodies, I found under them two red wings, the extremities of which were folded together, because, being longer than the cases, they cannot otherwise be covered by them. I also took off their wings, feet, and heads, and then I found, that the cavity which is seen on every grain of Cochineal, is on the back or upper side of the animalcule, and is caused by the drying; that part of the grain which appears with a kind of rising, is the lower part or belly. As to those grains in Cochineal, which have smaller cavities than others, I conclude, that they must have been the female insects, whose bodies, being filled with eggs, do not admit of their contracting in so great a degree; and though the hind parts of the bodies of those insects which compose Cochineal, do somewhat differ from those of the lady-birds, yet, I was now, more than ever, assured, that, not only the insect which produces the Cochineal, but also those others I have just mentioned, are formed from maggots or caterpillars. For, if we consider the nature of all those flying animals which are bred from caterpillars, maggots, or, what are called gentles, we shall find, that all those annular parts, articulations, or circular creases, which are in the caterpillars, maggots, and gentles, are also found in the flying insects bred from them; and in the same number. To instance in the gentle, from which the common fly is bred; if we examine the fly, and consider its head to be composed of one of the annular parts, or articulations in the gentle, we shall find that the breast to which are joined the six feet, contains three distinct articulations, and the hind part of the body five more. In a word, the body of the fly is divided

into nine several parts, joints, or articulations, and so many also are found in the gentle. This gives the reason, why we must not suppose, that the rings or creases which we see on the grains of Cochineal, are accidentally produced in the drying, for they were completely formed in the maggot, from whence the flying insect issued, the hinder part of whose body constitutes that substance named Cochineal; of which, if we examine the grains, we shall find them to contain ten articulations; and the fore part of the insect's body, which includes the head and feet, and the wings with their cases, being composed of four joints or rings, it follows, that the Cochineal insect is formed of fourteen joints, rings, or articulations.

After I had left the grains of Cochineal in water, for the space of twenty-four hours or upwards, I observed, that the cavity, which had been caused in them by the drying, was swelled and extended to its original shape, so that the grains appeared exactly to agree, in form and make, with the hinder parts of those insects, whose wings and bodies are covered with shells or cases.



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An account of some pieces of Amber presented to the Author; also of a substance resembling burnt paper, reported to have fallen out of the clouds in Courland.

A Prussian Gentleman, by profession a physician, on a certain time, earnestly requested me, by letter, to receive a visit from him, and, with the same letter, transmitted to me, some small pieces of Amber, which, he said, were sent as a present to me, from some persons of note in Prussia.

In these pieces of Amber were several small animals, namely, a Fly, a Gnat, a Spider, and an Ant. In the two first of these creatures, I not only plainly saw the wings, but, by the microscope I could discover the feathers and hairs on them, and also those protuberances or appearances like coral beads, of which the eyes of those insects are composed; I also saw the hairs, and nails or claws on all of them, as plainly as if they had been placed before the microscope, without any intervening medium. In one of these pieces of Amber, I saw a little piece of straw, in which I could distinguish the tubes or vessels of which straw is composed.

The manner how these animalcules became inclosed in the Amber, and the nature and composition of Amber, are equally unknown to me; and I cannot subscribe to the theories or opinions of others, which do not seem sufficiently supported, nor am I at present particularly called upon, to make any farther enquiry into this matter.

The same Gentleman, among other subjects of conversation, told me, that in Courland, there had been found in a field, something resembling burnt paper, being as much as two or three sheets in quan-

tity, which it was reported had fallen from the clouds; that he had procured a piece of it, which he had examined by the microscope, but could not form any satisfactory judgment respecting it. And, finding me desirous of seeing this pretended paper, he afterwards sent me a piece of it.

I had not had this supposed paper in my possession half an hour, before I obtained, by the help of the microscope, so much insight into its nature, that I judged it to be a vegetable production, of a sort which grows in the water; and I concluded, that if the fact was, as reported, that it had fallen from the upper region of the air, it had been carried up thither by what is called a water spout; though I am much more inclined to believe, that by some heavy storm of rain, or the melting of snow, (if the country is mountainous) the ponds or ditches might have overflowed, and carried with their current this vegetable production while green, leaving it on some field of grass or arable land, and there, by the sun and wind, it might be very much dried, so as, in some measure, to resemble burnt paper: moreover, I was well assured, that I had seen this kind of substance in considerable quantities in ponds, ditches, or canals, in this country; my only difficulty was, to discover, how it acquired the black or apparently burnt colour before mentioned.

To satisfy myself in this respect, I went to some stagnating pieces of water in the neighbourhood of this town, where I had seen this vegetable, which is an aquatic plant or weed, in great abundance, some of it I brought home with me, and spreading it open between pieces of thick paper, I laid it before the fire to dry. I then perceived that where many pieces lay heaped one on another, their natural green was changed to a blackish cast; but, where the pieces lay singly, they preserved their green colour.

After this, I examined the before mentioned imaginary paper more accurately, and I saw very distinctly, that it was exactly of the same

make and texture, with the pieces of green plant or weed I had gathered; and, upon examining this last, when in the same state as I took it out of the water, I saw by a common magnifier, what seemed to me like very thin threads in it, much finer than hairs; they were round, and their membranes or coats very transparent, and they were filled with great numbers of green globules, of different sizes, the most of them about the sixth part as large as a globule of the human blood. And though this green weed, when I first laid it to dry, was in parcels heaped together, to the thickness of one's little finger, yet, when dried, it was no thicker than common paper, whence may be gathered, what a vast quantity of watery particles are contained in this aquatic plant or weed.

In a word, this supposed paper from Courland, which is there reported to have fallen from the clouds, and the green weed or leaf, prepared by me in imitation of it, are, in their component parts, so exactly alike, that they may be said to be one and the same. For, in divers of the filaments or threads of the first, I could perceive the membranes composing them to be the same as in the second, and, in an hundred places, I could perceive these filaments to be furnished with joints, which were alike formed in each specimen.

These observations shew, how far conceit and imagination will lead some people, and who knows, how many persons may have pieces of this imaginary paper, treasured up in their cabinets as great rarities?



Of the herb Periwinkle, wherein the opinion that it does not bear any seed, is refuted.

I WAS induced to turn my thoughts to the confideration of the herb Periwinkle, from an opinion which is entertained, that, though it bears a flower, it does not produce any feed. I therefore procured some blossoms or flowers of this herb, as they grew on the stalks, for I was well assured, that no flower is produced by any plant, which, when it falls off, is not succeeded by some kind of feed. And, upon examining by the microscope these flowers, and the remains, as I may say, of some of them, which adhered to the stalk, in the places where the flowers had fallen off, I very plainly saw, that these remains were formed for the particular purpose of producing feed; for, in some of them, I saw two or three seeds, though very minute.

An acquaintance of mine, a respectable person, gave me some of these flowers, which he had gathered from a plant, growing in a place, where the rays of the sun seldom penetrated: and the same person, passing by a house, where this plant was placed as an ornament, and observing that there were some seeds on it, he brought me a few of those seeds with the shells or pods inclosing them. These seeds were of a dark colour, oblong, and much larger than I expected to have seen, and they were inclosed in a strong and tough shell. They were not much shorter than coffee berries, though the coffee berries are four times as thick; and lastly, the seeds of

the Periwinkle are distinguishable by the same kind of crease or chink, as is to be seen in coffee berries.

Six of these seeds, I steeped in water for several hours, in order that I might be able to cut them, through the hard shell or husk, into very thin slices; and, upon placing those slices before the microscope, I saw, in every seed, the young plant concealed. I saw likewise, in several of them, the two leaves with which these kind of young plants are generally provided, and these small leaves, which, in dissecting the seed, I had cut through, appeared somewhat of a flat shape: I also could distinguish the veins and vessels in these leaves. Upon repeating the experiment, I cut through that place in the seed which partly shoots upwards into a stalk, and partly penetrates downwards into a root. And here, I could discern the vessels, destined to convey the juices upwards or downwards, to those respective parts of the plant. In some of these seeds, however, the young plant was not compleatly formed.

After this, I cut the outer husk or shell, and the farinaceous substance which surrounded the young plant, into very small pieces lengthwise, in order to take the young plant, whole and entire out of the seed. And having succeeded therein to my wish, I clearly perceived in the plant the two oblong leaves I have mentioned, with their vessels and veins; and I farther saw, that the sides of the leaves, which lay next each other, were somewhat flat, the outer sides of them rounding. The vessels on the sides of the leaves, on account of their opacity, I could not perfectly distinguish. The young plant, inclosed in the seed, I judged to be sixteen times smaller than the seed itself.

The young plant in the seed of this herb, Periwinkle, is remarkably long and slender; the plant itself does not rise up into a stalk, but creeps along on the ground. And, as in this respect, it is similar to most plants of the vine species, which are by nature what is called

creeping, and therefore are usually trained against some support; so, the young plants, in the seeds of the Periwinkle, and in that of the Vine, I mean, what is contained in the grape-stone, are of a similar shape, though the seeds themselves, are wholly of a different figure: and, as to the circumstance, that seeds are seldom found in the Periwinkle, whence the notion of its being entirely destitute of seeds, seems to have proceeded, I guess this to be the reason, that, it is generally planted in the most obscure and unfavourable places, where it receives very few of the sun-beams.

Moreover, I examined the mealy substance which surrounds the young plant, and found it to consist, in part, of vesicles, of equal sizes, but much larger, than the vesicles which are found in the cocoa-nut. When I strongly compressed these mealy particles, I observed many oily parts, of a globular form, and so large, that they seemed to be composed of many receptacles of that oil.

Finally, I placed six of the Periwinkle seeds in moist sand, which I put into a strong and large glass tube; this I carried, for the space of an entire month, in my pocket, where, in the day-time, the natural heat of my body was imparted to them; and, at the expiration of that time, I took out one of the seeds, but, I did not perceive any alteration in it. I therefore kept the remaining five seeds in the sand, taking care, that they should always be moist. And, at the end of another month, I again examined them, but found their figure unaltered, though the seeds were grown so soft, that, they might be broken with one's nail only. I then took the young plants out of the seeds, and I could not observe in them any tendency towards decay or dissolution, nor any advance towards vegetation or increase.

E e



*Of the root named * Pareira Brava.*

SEEING, in the Philosophical Transactions of the Royal Society of London, the Root named Pareira Brava, very much extolled, on account of the medicinal virtues it is said to possess, I was induced to publish the observations I had made on that root.

A gentleman of some consequence in this country, produced to me a piece of this root, adding, that it was difficult to be met with, and was very highly valued, for that a few grains of the powder, administered to a sick person, would be found of singular benefit.

In order to examine this wood by the microscope, I obtained from this gentleman a small piece, from which I cut off about the quantity of a grain, and this again, I divided into still smaller slices, some by a longitudinal, and some by a transverse section. I then, by the help of the microscope, discovered, that the wood contained many very large pores, in some places disposed singly, in others, two or three placed adjoining to each other. I next, put these very thin slices into a perfectly clean glass, and poured water on them, in order to separate from them, the salts they might contain, which I was very desirous to examine. Then, upon applying the microscope, I observed great numbers of excessively minute, glittering particles disposed throughout the water. These particles were of various and peculiar shapes, very like those salts which I have often

* This is the root of an American convolvulus, (the *cissampelos Pareira* of Linnæus): brought to us from Brazil. The reader will find it described in the New Edinburgh Dispensatory, being an improvement of Dr. Lewis's.

found in sea-fish. Then, because I imagined that these particles, as far as I could judge by my eye, were no other, than absolute salts, I immerfed some of them in burnt wine, to fee whether they would be diffolved in the wine. But, all of them preferved their fhapes unaltered, fome of them exhibiting on the glafs, a triangular figure, and fome being perfectly fquare. But, it was my opinion, that thefe falts, had been inclofed in certain veficles in the root, and, when extracted from them by the water, had concreted into the falts I have defcribed; for, I had obferved the Pareira Brava to be furnifhed with many of thofe veficles.

Not having fully fatisfied myfelf by the examination of this piece of the Pareira Brava, I endeavoured to purchafe fome of the root in our town, but I found, that the very name of it was unknown here; however, in a neighbouring town, where it had been in ufe for about a twelvemonth, I procured an ounce and a quarter, and, upon comparing this with the former fpecimen, by the help of the microfcope, I found them to correfpond exactly.

This laft-mentioned root, was a piece, fplit lengthwife, and, as near as I could judge, of five years growth: it was half an inch in thicknefs, and the texture of it appeared to me of a wonderful make.* I divided a fmall piece of it, into very minute fragments, and, putting them into a clean glafs with fome rain water, I caufed the water to boil, until more than half of it was boiled away, the remainder I took off the fire, judging, that the faline particles, were, by this boiling fully incorporated with the water. In this water, however, I difcovered nothing by the microfcope, except feveral very fmall and thin membranes fwimming on the furface: I therefore expofed fome drops of it to the air, in order, that the evaporation of the moiſture might caufe the falts to concrete. But, in a ſhort time,

* The author has not given a figure of this root.

there appeared such a membrane or film on the surface of the water. that nothing could be distinguished in the fluid, except some excessively minute particles swimming in the water in such multitudes, that, if some of them had not collected together in the form of salts, I could not have discovered them. And, I could not sufficiently admire, that from so small a fragment of the root, such a quantity of salts had passed into the water.

After this water had stood undisturbed for some time, and the films on it were subsided, I put a drop of it, about the size of a pin's head, into a clean glass, and mixed with it some blood, which, by the puncture of a needle, I drew from my finger. Whereupon I saw, that the globules of blood from whence its redness proceeds, were, upon being thus diluted, more separated and scattered than I remember to have ever observed. There was also this remarkable appearance, that most of the globules had a kind of sinus or cavity in them, the same as if one had a bladder filled with water, and by pressing a finger on the middle of the bladder, made a cavity or furrow in it. And, when the globules, after assuming a flat shape (for when they are somewhat dispersed or separated, their extreme softness causes them to become flat) got somewhat closer together, they put on an oval figure, and then, the cavities I have mentioned, also became somewhat oblong. But, when globules of blood are concreted or coagulated, they exhibit the appearance of a solid body, the component parts of which, cannot be distinguished by the eye, except that, in the coagulated parts, they seem rather to differ in size.

Now, having so often experienced as I have done, how very soft are the globules of blood, and how speedily, when slightly in contact, and exposed to the air, they coagulate, I cannot, in any manner, comprehend, how it is, that those globules when in the veins and arteries, where they so strongly propel and compress one another, do not coagulate. Still less can I comprehend, why, when

the skin, or the arteries, are compressed with the hand, the blood itself does not become thicker.

After this, I cut the root into many small pieces, both longitudinally and transversely, in order to investigate, whether those minute salts, which I deemed to be in the root, could be there discovered. For, I was persuaded, that there were in the root, some kind of vesicles, full of a certain humour or moist substance, and, that upon the evaporation of the moisture, the saline particles which abounded in it, concreted together, as I have mentioned above.

Having now plenty of the root, to pursue my experiments, I found, that more than one-third part of it, consisted of vesicles, arising at the inner part of the root, and tending towards the exterior. In these vesicles, lay certain minute salts, collected as it were in clusters, so that frequently, six or seven appeared together, in a circular position: and, where these clusters were longer than broad, I judged that, at least there were twenty salts in every cluster.

These particles, in my opinion, when first formed in the root, are larger; but, that in the drying, they become so closely compacted together, that they each assume different shapes, some being triangular, some quadrangular, &c. which I have also observed, in most things when heaped together promiscuously. From hence, at length I gathered, that these small particles, were no other than very minute salts.

For my farther satisfaction herein, I took some of these very minute salts out of the membranes or vesicles containing them, and after wetting them with rain-water, I put them into a very clean glass, and placed them over a burning coal, in like manner as I have practised in experiments on the globules of meal. I then observed, that these particles, which, for the present, I will call mealy particles, and which, before, were globular, now assumed a flat shape of a circular figure. So that, these particles may, perhaps,

without impropriety, be deemed farinaceous or mealy parts; for, as I have said, their globular form was changed to that of flat and circular, but of different dimensions. This experiment I often repeated, and always found the event alike.

Having never before, found these collections of particles surrounded by a membrane in any other wood, but only in certain seeds, I was not content with the examination of this root, Pareira Brava, but applied myself to the inspection of other roots, such as that of the China root*, in which, I not only found the same kind of substance, or particles, as in the Pareira Brava, but, the particles were so very large, that I could very plainly perceive in them, the same kind of chink, furrow, or crease, as I have in another place mentioned, to have observed in the grains and meal of wheat. And, as to all these mealy particles, in both the subjects I have mentioned, I could perceive them, when brought to the fire, uniformly alter their figures, from a globular, to a flat and circular shape.

Now, since it appears, that the particles in the last-mentioned root, have in them these chinks or creases, and, that when wetted and afterwards dried, they change their figures as before related, we may reasonably conclude, that the very minute particles which abound in the Pareira Brava, have also the same kind of chink, or furrow, though such furrow is to us invisible.

Let us now suppose these very minute particles, which I call mealy ones, contained in the root of the Pareira Brava, to be administered as a medicine, and by the heat and moisture of the body to be dissolved: let us farther suppose that the particles, so dissolved, are, by the continual motion and agitation of the body, in order, that they may perform their office of restoring health, comminuted and broken into other particles of inconceivable tenuity

* This root is very minutely described in Dr. Astruc's Treatise on the Venereal Disease.

and fineness. We do indeed, hereby gain some insight into the manner of Nature's operation of healing; but, in what particular manner, the particles, so attenuated, do act in the accomplishment of her purpose, will, if I mistake not, for ever remain undiscoverable by human powers.

Farther, I took a portion of the root, in quantity about five grains apothecary's weight, and placed it on the fire, in order to draw from it the oil and volatile spirit it might contain. When this was burnt to a coal; in order to discover its fixed salts, I poured on it a little rain water, which water becoming very turbid and foul, by reason of the burnt matter, I strained it through a filtering-paper, and placed portions of it on several pieces of clean glass, to the end, that the watery parts might evaporate. Nevertheless, there still remained something of a viscid matter, from whence I concluded, that some parts of the root had escaped the fire: this was all that occurred to me worthy of note in this experiment.

A certain physician, in conversation on the subject, suggested to me, that if the coal of the root was burnt to a white ash, the salts would certainly be discovered. But, though, in attempting to effect this, the glass on which the pieces of root were placed, always melted by the violence of the heat, the pieces of wood were never burnt to ashes.

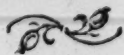
Hereupon, I placed some pieces of the Pareira Brava root, on a piece of charcoal, such as the goldsmiths use, and directed the flame of a large candle against it, by the blast of a blow-pipe; by which means, the root was almost all consumed to a white ash: this, I cast into a small quantity of water in a glass, and filtering the water, which was very turbid, I let it fall drop by drop on different glasses, made perfectly clean. One of these glasses I placed on a burning coal, in order to evaporate the moisture, for, at that time, the atmosphere was very damp, and rainy. When this drop of wa-

ter was evaporated, such a quantity of salts appeared, that I was astonished at the sight; for they lay heaped together, in like manner as, in a wood, the twigs and small branches are seen spread on the ground. After they had remained thus for a small time, though within an hour, they dissolved into moisture: I found the same effect to follow breathing on them.

Now, what shall we say of this most extraordinary and intimate union of these salts with the root? For, it has been observed, that though the glass melted by the vehemence of the heat applied to it, the salts in the pieces of root, which lay on the glass, were not expelled; though afterwards, when surrounded by a stronger heat, they were separated from the wood.

When we find these things upon experiment, we cannot but reason thus with ourselves; How wonderful is the make and texture of this root, and how powerfully may the salt which is thus closely united to it, act as a medicine on the human body! For my part, if I may speak my opinion, it is, that the make of these salts is not to be altered by the power of fire.

Again, upon considering whether the charcoal, which I had used in the preceding experiment, might not possibly have some foulness or extraneous matter on it, which was imparted to the root whilst burning, I placed some pieces of the Pareira Brava on a silver plate, and, when they seemed to be quite burnt to ashes, and were glowing hot, I threw them into some rain water, which had been boiled in a clean vessel well tinned, and only used to boil water for the making of tea or coffee. This water, after straining it through filtering paper, I placed in four separate glasses, and suffered it to remain there all night. The next day, the atmosphere being dry and clear, I examined them by four several microscopes, and found, that the greatest part, but not the whole, of the water was evaporated. The event of the experiment was, however, the same as in the last, namely, that an innumerable multitude of the salts before described, were to be seen, and that more distinctly than before.



On the formation of the crystalline humour of the Eye, in various animals, birds, and fishes.

THE crystalline or transparent body or substance, (which is commonly called the crystalline humour) of the Eye, is, in consistence or hardness, almost the same as a preserved nutmeg. When I first began to make my observations on it, I cut off, with a sharp razor, some small pieces or slices, and found it to consist of a sort of scaly particles, laid one on another, in a kind of circular form, taking their origin from the center, and all of them then seemed to me, to be composed of crystalline globules. After I had left this crystalline substance, for the space of three days to dry, it became so hard, that it flew into pieces before the edge of the knife, after the manner of rosin. Upon again examining its nature and composition, I perceived, not only the scaly formation, and in the circular direction I have mentioned, but I discovered, that each of the scales or coats was composed of parts, lying in a circular position, and in regular order, in respect to each other. In other words, the formation of the crystalline humour, may be compared to a small globe, or sphere, made up of thin pieces of paper, laid one on another: this will serve to give an idea of the scales or coats above mentioned, and, supposing each paper to be composed of particles or lines, placed somewhat in the position of the meridian lines on a globe, extending from one pole to the other, this may explain the nature of the component parts of those scales or coats.

After these first observations, I employed myself, more narrowly to examine, the eyes of oxen and cows; for, I thought, that I had

not then, investigated the formation of the crystalline humour, so accurately as I ought to have done.

I, therefore, first sat about examining that pellicle or thin membrane, wherein the crystalline humour is inclosed, and by which it is, as it were, separated from the other humours, composing the substance of the Eye. I was then, well assured, that I saw this membrane to be composed of threads or filaments, though afterwards, notwithstanding the greatest attention that I could bestow, I could not distinguish such filaments.

In this examination, I sometimes, but not often, observed, that the small fibres composing the filamentary substance of the external coat of the crystalline humour, were united to the before mentioned membrane; whence I concluded, that this membrane was essential to the crystalline humour, in order to smooth any inequalities that there might be in the filaments of its external coat, and make its round surface perfectly even.

I also considered with myself, whether this membrane might not be formed, for the purpose, occasionally, by its compression, to alter the figure of the crystalline humour; that is, to make its rounding shape flatter at times, as the purposes of vision might require; and, if so, this part of the Eye which has hitherto been called the crystalline humour, ought rather to be named, the crystalline muscle of the Eye: and yet, I cannot affirm with certainty, that I have clearly seen this membrane to be composed of filaments intermixed one among another, though, I am well assured that it cannot be formed in any other manner; for, I have always found every kind of thin membrane which I examined, to be of a filamentary or fibrous make. With regard to this, now under consideration, I perceived, when viewing it sideways, that it was composed of a kind of streaks perfectly transparent, which I concluded to be, some lymphatic vessels, destined for the nourishment of the crystalline humour; but

when I followed with my eye, these streaks, or lymphatic vessels, to the part where they joined the crystalline humour, they became so slender, that they vanished from my sight.

With regard to the before mentioned scales or coats, which compose the crystalline humour, I found them to be so exceedingly thin, that, measuring them by my eye, I must say, there were more than two thousand of them, lying one on another. For, when I had stripped the crystalline humour of the membrane in which it was inclosed, I found, that its axis or diameter where it was thickest, (for it is not a perfect globe, but somewhat flattened) was equal to two third parts of an inch; therefore, from the center to the circumference, is one third of an inch; and, as I have found by repeated experiments, that six hundred hairs of a man's head, are in breadth equal to an inch, two hundred of them constitute the third of an inch. Now, I have seen, that where ten of the before mentioned scales or coats lay close, one on another, they were not, altogether, equal to the diameter of an hair; therefore, if these ten be multiplied by two hundred, it follows, as I have before mentioned, that the crystalline humour is, in its substance or thickness, composed of more than two thousand scales or coats: and lastly I saw, that each of these coats or scales was formed of filaments or threads, placed in regular order, side by side, each coat being of the thickness of one such filament.

In order to explain to the reader, the nature of this formation of the crystalline humour, that is, how it is composed of fibres or filaments, I have, in the following figures, represented those filaments by lines drawn in a circle, as accurately as I was able; first premising, that in Plate VIII. *fig. 1.* ABC represents the crystalline humour, in an ox's eye, of its natural size; B, is the place in that part of the tunica cornea, or horny coat of the eye, through which the rays of light pass. In the following figures, the natural dimensions are increased, in order that the filaments of which the scales or coats are composed, may be exhibited more distinctly.

In Plate VIII, at *fig. 2*, is represented the surface of the crystalline humour, pictured at *fig. 1*, but, which is here to be considered, as if that figure did present a circular shape to the eye. In this figure, are many lines to represent the course or direction of the filaments, but, it must not be supposed to give a true representation of their numbers, the circumference of the crystalline humour of an ox's eye, containing more than twelve thousand of such filaments. For, ten of these filaments laid side by side are, (as before observed) not equal to the diameter of an hair; and the whole axis or diameter of the crystalline humour being, as before noted, equal to four hundred hair's breadth, it consists of four thousand filaments in diameter. And, by the common rules of arithmetic, whereby we find the circumference of a circle, of a given diameter, it will be found, that the circumference of the crystalline humour in an ox's eye, consists of $12571\frac{3}{7}$ filaments.

Hence we may collect, how excessively thin these filaments are; and, we shall be struck with admiration, in viewing the wonderful manner they take their course, not, in a regular circle round the ball of the crystalline humour, as I first thought, but, by three different circuits, proceeding from the point L, which point, I will call their axis or center. They do not, on the other side of the sphere, approach each other in a center like this at L, but return in a short or sudden turn or bend, where they are the shortest, so that, the filaments of which each coat is composed, have not in reality, any termination or end. To explain this more particularly, the shortest filaments MK, HN, and OF, which fill the space on the other side of the sphere, constitute a kind of axis or center, similar to this at L; so that, the filaments MK, having gone their extent, and filled up the space on the other side, in like manner as is here shewn by the lines ELI, return back, and become the shortest filaments, HN. These filaments HN, passing on the other side of the sphere, again form another axis or center,

and return in the direction OF, and the filaments OF again, on the other side of the sphere, collect round a third center, and thence return in the direction KM; so that, the filaments which on this side are the shortest, on the other side are the longest, and those which there are the shortest, are here the longest.

In order to exhibit more clearly to the view, the nature and disposition of those filaments, constituting each scale or coat of the crystalline humour, I have given a figure of them, as seen sideways, and which, in the plate, is expressed by lines; but it must be observed, that in these figures, the crystalline humour is represented as if it were of a spherical form, and, in the description I call it a sphere, as being more intelligible in the description, though in truth, it is not perfectly globular, as I have before noted.

In Plate VIII. *fig. 3*, RTPSWQ, is designed to represent one of the coats of the crystalline humour, allowing for the difference in shape as before noted: P, and Q are axes or centers, one of which, P, in *fig. 2*, was shewn at L; the filaments coming from the point P, (which in *fig. 2* is L) proceed to V, where they are shortest; from whence they return towards P, where again they are longest, and, from P they proceed towards W, where they are again shortest. In like manner, the filaments at T, take their direction towards Q, and from thence towards X, and from X again towards Q: so that, in this figure (allowing it to be considered as an hemisphere) may be seen the one half of the course or circuit of the filaments. In a word, the filaments LI, in *fig. 2*, are the same as in this, are shewn at PS; and the filaments between L and M in *fig. 2*, are here seen between P and X, and those between L and O, in *fig. 2*, are here, between P and T; so that the filaments which in *fig. 2*, are seen between FOLIKE, and in *fig. 3*, in RTPS do represent the self same filaments.

I must here farther observe, that the filaments, of which the crystalline humour, or rather substance, consists, are thickest about R

and S, and, where they approach nearer, at P or Q, they become thinner or slenderer. Finally, upon an attentive examination of the crystalline humour, we shall be convinced, that its transparency is not to be exceeded by any glass, although it consists of so many thousand filaments, which is most wonderful; and the more, if we consider, how closely the filaments must be united, that they may admit the rays of light to pass through them in strait lines; for otherwise, the crystalline humour would not be pellucid, but would exhibit a white appearance.

In order to explain this formation of the crystalline humour still more plainly to some curious gentlemen, I took a small tennis ball, and wound it close round about, with some very small twine, confining the twine by pins stuck in the ball, in the position or course which the filaments take; I then spread over the whole some strong glue, and when it was dry, I took out the pins, and then the twine thus wound round the ball, gave a true representation of the course of the filaments as before described.

I have mentioned in the beginning of this Essay, that the parts which I now plainly perceive are filaments, I then thought were composed of globules, and this, in some filaments, did then seem to me very apparent; but, not having seen the same appearance uniformly in all, I now conclude, that the filaments being (as before mentioned) most closely united, it might happen, that in the separating them, some fragments or particles of one, might stick to another of them, and these I might mistake for globules.

After this, I took the eyes of sheep, hogs, dogs, cats, and other animals, and examined their crystalline humours, in the same manner as I had treated the eyes of oxen; but, neither in the scales or coats constituting the crystalline humours, nor in the disposition of the filaments, of which each coat or scale was composed, did I perceive the least difference. Moreover, I extracted the crystalline humour,

from the eyes of hares and rabbits; these also, I found to consist of scales or coats, inclosed one in another, and each scale or coat composed of filaments; but, whereas the filaments composing the crystalline humour in the eyes of the several animals I have first enumerated, do arise from three centers, and thence are dispersed three different ways round the circumference, the filaments in these two last mentioned animals, take only a twofold course or direction. This is shewn in *fig. 4*, *ABCD*, which represents the hemisphere, or one half of the crystalline humour, in the eye of an hare or a rabbit. *E*, is the center near the pupil or sight of the eye; these filaments, composing the coats or scales, passing through, or near the central point *E*, take their course, some towards *F*, and others towards *G*, so that *F* and *G*, on the contrary side, constitute another central point.

I also made a drawing, which is copied at *fig. 5*, of the same object, as it appeared when viewed sideways, in order more clearly to shew the nature of these last mentioned filaments, which, with a kind of fibrous substance, compose each scale or coat. I will suppose then, that the filaments, which in *fig. 4*, are represented between *E F*, are the same which in *fig. 5*, are pictured at the letters *IO*; so that, the filaments proceeding from the point *I*, that is, in the former figure at *E*, here end their course at *N* and *L*, where they are the shortest, and those at *O*, take their course through or beside the point or center *N*, where they are the longest, and then terminate, or rather, with a kind of flexure or bending, return as here represented. In a word, those filaments, which, on this side, appear nearest the center, would, on the farther side be seen remotest from it.

In these experiments, I always endeavoured, to discover the formation of that part of the Eye which anatomists call the vitreous or glassy humour, and, which in great part, surrounds the crystalline humour, because I was well assured, that this vitreous humour, was

not a watery substance, but rather a kind of pellucid muscle; but, notwithstanding all my endeavours, I could not form any determinate or certain judgment on this head, because the substance of this vitreous humour, always changed into a kind of watery matter.

Moreover, I examined the eyes of fishes; these are perfectly spherical, and I found, that they consisted of the same kind of thin coats or scales, laid one on another, as I have described the eyes of animals to be formed; each coat or scale, was also composed of filaments, but, these filaments have not that kind of bending course, as in animals; and, with all my endeavours, I could not discover in what direction they were placed; for, where the filaments draw towards a point or center, they are so exceedingly slender, and cohere so closely, that they escape the sight, and cause such a confusion of objects, that I cannot be certain, whether they terminate in that center, or return back again from it. *Fig. 6*, ABC D, represents the crystalline humour or substance in the eye of a cod-fish; and, though I drew the lines, here made to represent the filaments, from the center or point A, to the center or point C, with only a pair of compasses, wider apart than in the other figures, yet the filaments which compose these scales or coats, are not in fact thicker, except in the middle at B and D, and the nearer they approach the point A or C the thinner they are. *Fig. 7*, shews the natural size of the crystalline humour in this eye.

I also examined the crystalline humour in the eyes of birds, only to see how the filaments composing their coats or scales, took their course; and, at length, after many observations, I found the filaments, in the eye of a turkey, to take the same direction, as those in fishes: but whereas the crystalline humour in the eyes of fishes is perfectly round, that in the eyes of birds, is flattened, as at *fig. 8*, lying with its flat side D, next the tunica cornea or horny coat of the eye. And, upon my cutting with a sharp knife many pieces of the scales or coats

composing it, in order to reduce the size smaller, it altered its figure to an oblong and flat shape, as shewn at *fig. 9*, where E is the same part which, in *fig. 8*, was shewn at D; being the point where the filaments are united, or, in other words, where they so closely approach, and are so exceedingly slender, as to become invisible: hence we may conclude, that the filaments which lie nearest to the central point, being very thin, do thereby produce the oblong round shape, and, where the crystalline humour is larger, the filaments in the middle are thicker, and thus cause the shape to be flattened, which I myself have seen; for the filaments in the eye of a turkey, where they were thickest, were, singly, larger than those in the eye of an ox, hog, or sheep.

I have often, while looking in a mirror, taken notice of that liquid substance or moisture, with which the exterior membrane or coat of the eye is covered, and, in which liquid, there are always some few very minute globules intermixed; which moisture, and the globules in it, as often as we shut our eye-lids are thereby made to change their places: seeing this, I gathered the reason, why it is necessary for terrestrial animals to be furnished with eye-lids (for fishes, and other inhabitants of the waters do not need them) and, that if it were not for the eye-lids, we should become blind; because if the eye-lids did not continually, when we close them, moisten the external membrane or coat of the eye, its surface would grow dry, and contract in wrinkles, especially in strong sunshine, or when we approach a large fire. And I think it very probable, that there is continually, some kind of humour or moisture, protruded from the inner part of the eye through the tunica cornea, which, by the eye-lids, is spread over the eye: for, in several eyes of hogs, whose bodies had been immersed in hot water, to facilitate the scraping off the hair, I almost always saw a thin membrane, lying on the outer surface of the tunica.

G g

cornea, which was somewhat scalded by the water, and therefore might easily be taken off; and, upon compressing the ball of the eye between my fingers, I saw in many places, a thin watery matter, issue from the tunica cornea, and appearing on its surface, like vapour or steam, adhering to a glass, and, when the pressure was continued, the watery particles, which stood on the surface, in the form of minute drops, were so much enlarged, as to run into one another. And we need not wonder at this appearance, when we consider, that the tunica cornea is composed of nothing but particles, like streaks or fibrous parts with their ramifications, and all of them very thin and slender.

I at one time cut the tunica cornea of an ox's eye into such thin slices, that the thickness of it was seven times divided, and, in each of those seven parts, I saw with great admiration (and more distinctly than I had before done) the great multitudes of pellucid streaks or fibres intermixed together, many of which I judged were a kind of blood vessels, though so small and slender, that they would not admit the globules of blood, which cause its red colour, to pass through them; and I conclude that, when we rub our eyes, those vessels may, by the pressure, be so extended, as to admit the red globules of blood, which, for a time, stagnating there, cause the eyes to appear red, or, what is commonly called blood-shot.

But, to return to the eye-lids, it is my opinion, that they never can be considered as in a state of rest, except when they are shut; and hence it is, that we cannot keep them steadily open, for any length of time, without applying some external force: and, as it were, to give them rest, we frequently (and involuntarily) close them; which involuntary motion in the eye-lids, does, I doubt not, by pressing on the orifice of some minute lymphatic vessels, cause them continually to emit small portions of the lymph, whereby the tunica cornea is continually kept moist, as has been before observed. And I have seen persons, in a public audience, when very attentive, close their eyes, though some did this more frequently than others.

Myself, and those of my family, have often, when contemplating objects by the microscope, seen an appearance of small globules before the sight, * which, I have no doubt, were particles issuing from the vessels in the eye, and lying on its surface: these, with the least motion of the eye, seemed to be in great agitation, and many would affirm, that they saw living creatures before their sight; but whoever gives this subject an attentive consideration, will find, that these globules or streaks, though they seem, while the eye is kept still, to be in motion, sometimes upwards and sometimes downwards, yet they do not alter their position in respect of each other; and perhaps at another time we shall see none, or if any, of a very different kind. I believe, however, that this appearance is what has led some people to fancy, that they beheld animalcules moving in water, even after it has been boiled, and to affirm, that these are the same kind of animalcules which I profess to have plainly seen: but we must forgive such persons their error, considering they know no better.

* The Translator can give a strong similar instance, from his own painful experience; for, having met with an accident by which the surface of his eye was injured, the consequence was, for some hours after the hurt, an appearance of minute, wonderfully bright globules, seeming to whirl round the ball of the eye with a rapidity like lightning; and, for several following days, many dark specks, in motion before the sight; but all, as Mr. Leeuwenhoek says, preserving the same distance in respect of each other: one of these in particular, appeared in size, colour, and shape, much like a common fly, which seemed to be running along the wainscot of the room, or upon the table.



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ADDITION, BY THE TRANSLATOR.

THE preceding Essay is one of the most curious, and the Translator conceives, that his Readers will deem it the most interesting, of any in this Work; forasmuch as it respects the choicest corporeal gift of God to his creatures, the Blessing of Sight: and, for the information of those, who are not acquainted with the particular structure of that wonderful Organ, the Eye; the following description of it is subjoined, taken from Mr. Adams's Essay on Vision, a small Treatise, well worthy the perusal of every one.

“OF THE GLOBE OF THE EYE.

“If the construction of the Universe were not so evident a proof of
“the existence of a supremely wise and benevolent Creator, as to
“render particular arguments unnecessary, the structure of the eye
“might be offered as one, by no means the least; this instance,
“among numberless others, demonstrating, that the best perform-
“ances of art are infinitely short of those which are continually pro-
“duced by the DIVINE MECHANIC.

“The globe of the eye, or the organ of sight, may be defined in
“general as a kind of case, consisting of several coats, containing
“three pellucid humours, which are so adjusted, that the rays pro-
“ceeding from luminous objects, and admitted at a hole in the fore
“part of the eye, are brought to a focus upon the back part of it,
“where they fall upon a soft pulpy substance, from whence the mind
“receives it's intelligence of visible objects.

“It is not to be expected, that any account given of the eye can be
“altogether accurate; for as it is impossible to examine all the
“parts of the eye whilst in a natural and living state, so it is also
“nearly impossible, when it is taken out of its socket, to preserve

“ the figure of the parts entire ; a circumstance which accounts for
 “ the disagreement we find among anatomists.

“ *Of the Coats of the Eye.*

“ The eye is composed externally of three coats, or teguments,
 “ one covering the other, and forming a ball perfectly globular, ex-
 “ cept at the fore part, which is a little more protuberant than the
 “ rest ; within this ball are three different substances called humours.

“ The first, or outer coat, is called the *sclerotica* ; the second, or
 “ middle one, is called the *choroides* ; the interior one is named the
 “ *retina*.

“ *Sclerotica. Cornea.*

“ The exterior membrane, which incloses and covers the whole eye,
 “ is called the *sclerotica* and *cornea* ; it is, however, strictly speak-
 “ ing, but one and the same membrane, with different names appro-
 “ priated to different parts : the hinder and opaque part being more
 “ generally denominated the *sclerotica*, the fore and transparent part
 “ the *cornea*.

“ The *sclerotica* is hard, elastic, of a white colour, resembling a kind
 “ of parchment ; the hinder part is very thick and opaque, but
 “ it grows gradually thinner as it advances towards the part where
 “ the white of the eye terminates. The fore part is thinner, and
 “ transparent ; it is also more protuberant and convex than the rest
 “ of the eye, appearing like a segment of a small sphere applied to
 “ a larger, and is called *cornea*, from its transparency. The *cornea*
 “ is thick, strong, and insensible ; its transparency is necessary for
 “ the free admission of the light. This membrane is composed of fe-
 “ veral plates, laid one over the other, replenished with a clear
 “ water, and pellucid vessels ; these plates are more evidently dis-
 “ tinct in the fore than the hinder part. The *sclerotica* is embraced

“ on its outside by fix muscles, by which the eye may be moved in
 “ any direction.

“ *Choroides. Uvea. Iris.*

“ Under the sclerotica is a membrane, known by the name of the
 “ choroides ; it is a soft and tender coat, composed of innumerable ves-
 “ fels ; it is concentric to the sclerotica, and adheres closely to it by a
 “ cellular substance, and many vessels. This membrane is outwardly
 “ of a brown colour, but inwardly of a more russet brown, almost
 “ black. Like the sclerotica, it is distinguished by two different names,
 “ the fore part being called the *uvea*, while the hinder part retains
 “ the name of the choroides.

“ The fore part commences at the place where the cornea begins ;
 “ it here attaches itself more strongly to the sclerotica by a cellular
 “ substance forming a kind of white narrow circular rim : the cho-
 “ roides separates at this place from the sclerotica, changes its
 “ direction, turning, or rather folding, directly inwards, towards the
 “ axis of the eye, cutting the eye as it were transversely : in the mid-
 “ dle of this part is a round hole, called the pupil, or sight of the eye :
 “ the pupil is not exactly in the middle of the iris, that is to say, the
 “ centers of the pupil and iris do not coincide, the former being a lit-
 “ tle nearer the nose than the latter.

“ This part, when it has changed its direction, is no longer called
 “ the choroides ; but the anterior surface, which is of different co-
 “ lours, in different subjects, is called the *iris* ; the posterior surface
 “ is called the *uvea*, from the black colour with which it is painted.
 “ The iris has a smooth velvet-like appearance, and seems to consist of
 “ small filaments regularly disposed, and directed towards the center
 “ of the pupil.

“ The eye is denominated blue, black, &c. according to the colour
 “ of the iris. The more general colours are the hazel and the blue,

“ and very often both these colours are found in the same eye. It has
 “ been observed, that in general, those, whose hair and complexion
 “ are light coloured, have the iris blue or grey ; and on the contrary,
 “ those whose hair and complexion are dark, have the iris of a deep
 “ brown: whether this occasions any difference in the sense of vision,
 “ is not discoverable. Those eyes which are called black, when nar-
 “ rowly inspected, are only of a dark hazel colour, appearing black,
 “ because they are contrasted with the white of the eye. The black
 “ and the blue are the most beautiful colours, and give most fire and
 “ vivacity of expression to the eye. In black eyes there is more
 “ force and impetuosity ; but the blue excel in sweetness and delicacy.
 “ The pupil of the eye has no determinate size, being greater or
 “ smaller, according to the quantity of light that falls upon the eye.
 “ When the light is strong, or the visual object too luminous, we con-
 “ tract the pupil, in order to intercept a part of the light, which
 “ would otherwise hurt or dazzle our eyes ; but when the light is weak,
 “ we enlarge the pupil, that a greater quantity may enter the eye,
 “ and thus make a stronger impression upon it. This aperture dilates
 “ also for viewing distant objects, and becomes narrower for such as
 “ are near. The contraction of the pupil is a state of violence,
 “ effected by an exertion of the will : the dilatation is a remission of
 “ power, or rather an intermission of volition. The latitude of con-
 “ traction and dilatation of the pupil is very considerable ; and it is
 “ very admirable, that while the pupil changes its magnitude, it pre-
 “ serves its figure.

“ Anatomists are not agreed, whether the iris be composed of two
 “ sets of fibres, the orbicular and radial, or of either. Haller says,
 “ he could never discover the orbicular fibres, even with a microscope ;
 “ the radial seem visible to the naked eye, and are sufficient to an-
 “ swer all the purposes required in the motion of the iris : when the
 “ pupil is contracted the radial fibres are strait, when it is dilated,
 “ they are drawn into serpentine folds.

“ In children this aperture is more dilated than in grown persons ;
 “ in elderly people it is still smaller than in adults, and has but little
 “ motion ; hence it is, that those who begin to want spectacles, are
 “ obliged to hold the candle between the eye and the paper they
 “ read, that the strong light of the candle may force their rigid
 “ pupils into such a state of contraction, as will enable them to see
 “ distinctly. Those who are short-sighted, have the pupils of their
 “ eyes, in general, very large ; whereas in those whose eyes are
 “ perfect, or long-sighted, they are much smaller.

“ The whole of the choroides is opaque, by which means no light
 “ is allowed to enter into the eye, but what passes through the pupil.
 “ To render this opacity more perfect, and the chamber of the eye
 “ still darker, the posterior surface of this membrane is covered all
 “ over with a black mucus, called the pigmentum nigrum. This pig-
 “ ment is thinnest upon the concave side of the choroides, near the
 “ retina, and on the fore side of the iris ; but is thickest on the ex-
 “ terior side of the choroides, and the inner side of the uvea.

“ The circular edge of the choroides, at that part where it folds in-
 “ wards to form the uvea, seems to be of a different substance from
 “ the rest of the membrane, being much harder, more dense, and
 “ of a white colour ; it has been called by some writers the ciliary
 “ circle, because the ligamentum ciliare (of which we shall soon
 “ speak) arises from it.

“ *Retina.*

“ The third and last membrane of the eye is called the retina, be-
 “ cause it is spread like a net over the bottom of the eye ; others de-
 “ rive the name from the resemblance of the net which the gladi-
 “ tors called *retiarii*, employed to entangle their antagonists. It is
 “ the thinnest and least solid of the three coats, a fine expansion of

“ the medullary part of the optic nerve. The convex side of it
 “ lines the choroides, the concave side covers the surface of the vi-
 “ treous humour, terminating where the choroides folds inwards.
 “ It is an essential organ of vision; on it the images of objects are
 “ represented, and their picture formed. This membrane appears to
 “ be black in infants, not so black at the age of twenty, of a greyish
 “ colour about the thirtieth year, and in very old age almost white.
 “ The retina, however, is always transparent and colourless: any ap-
 “ parent changes therefore, of its colour, must depend upon altera-
 “ tions of the pigmentum which is seen through it.

“ *Optic Nerve.*

“ Behind all the coats is situated the optic nerve, which passes out of
 “ the scull, through a small hole in the bottom of the orbit which
 “ contains the eye. It enters the orbit a little inflected, of a figure
 “ somewhat round, but compressed, and is inserted into the globe
 “ of the eye, not in the middle, but a little higher, and nearer to
 “ the nose; an artery runs through the optic nerve, goes straight
 “ through the vitreous humour, and spreads itself on the membrane
 “ that covers the back side of the crystalline.

“ Monf. Mariotte has demonstrated, that our eyes are insensible
 “ at the place where the optic nerve enters: if, therefore, this nerve
 “ had been situated in the axis of the eye itself, then the mid-
 “ dle part of every object would have been invisible, and where all
 “ things contribute to make us see best, we should not have seen at
 “ all; but it is wisely placed by the divine artist for this and
 “ other advantageous purposes, not in the middle, but, as we have
 “ already observed, a little higher and nearer to the nose.

“ *Of the Humours of the Eye.*

“ The coats of the eye, which invest and support each other, after

“ the manner of an onion, or other bulbous root, include its humours,
 “ by which name are understood three substances, the one a solid, the
 “ other a soft body, and the third truly a liquor. These substances
 “ are of such forms and transparency, as not only to transmit rea-
 “ dily the rays of light, but also to give them the position best
 “ adapted for the purposes of vision. They are clear like water, and
 “ do not tinge the object with any particular colour.

“ *Aqueous Humour.*

“ The most fluid of the three humours is called the aqueous one ;
 “ filling the great interstice between the cornea and the pupil, and
 “ also the small space extending from the uvea to the crystalline lens ;
 “ it is thin and clear like water, though somewhat more spiritous and
 “ viscuous ; its quantity is so considerable, that it swells out the fore
 “ part of the eye into a protuberance very favourable to vision. The
 “ uvea swims in this fluid. It covers the fore part of the crystalline ;
 “ that part of this humour which lies before the uvea, communicates
 “ with that which is behind, by the hole which forms the pupil of
 “ the eye. It is included in a membrane, so tender, that it cannot
 “ be made visible, nor preserved, without the most concentrated lixi-
 “ vial fluid.

“ It has not been clearly ascertained whence this humour is derived ;
 “ but its source must be plentiful : for if the coat containing it be so
 “ wounded, that all the humour runs out, and the eye be kept closed
 “ for a season, the wound will heal, and the fluid be recruited.

“ The colour and consistence of this humour alters with age ; it
 “ becomes thicker, cloudy, and less transparent, as we advance in
 “ years, which is one reason, among others, why many elderly peo-
 “ ple do not reap all that benefit from spectacles which they might
 “ naturally expect

“ *Cryſtalline.*

“ The ſecond humour of the eye is the cryſtalline, which is as
 “ transparent as the pureſt cryſtal; and though leſs in quantity than
 “ the aqueous humour, yet it is of equal weight, being of a more
 “ denſe and ſolid nature; in conſiſtency it is ſomewhat like a hard
 “ jelly, growing ſofter from the middle outwards. Its form is that
 “ of a double convex lens, of unequal convexities, the moſt convex
 “ part being received into an equal concavity in the vitreous humour.

“ The cryſtalline is contained in a kind of caſe, or capſule, the
 “ fore part of which is very thick and elastic, the hinder part is thin-
 “ ner and ſofter. This capſule is ſuſpended in its place by a muſ-
 “ cle called ligamentum ciliare, which, together with the cryſtalline,
 “ divides the globe of the eye into two unequal portions; the firſt
 “ and ſmaller one contains the aqueous humour, the hinder and
 “ larger part the vitreous humour. The cryſtalline has no viſible
 “ communication with its capſule, for as ſoon as this is opened the
 “ humour within flips clean out.

“ The cryſtalline is placed ſo, that its axis correſponds with that of
 “ the pupil, and conſequently it is not exactly in a vertical plane di-
 “ viding the eye into two equal parts; but ſomewhat nearer the noſe.
 “ It is formed of concentric plates or ſcales, ſucceeding each other, and
 “ theſe ſcales are formed of fibres elegantly figured, and wound up
 “ in a ſtupendous manner; theſe are connected by cellular fibres,
 “ ſo as to form a tender cellular texture. Between theſe ſcales is a
 “ pellucid liquor, which in old age becomes of a yellow colour. The
 “ innermoſt ſcales lie cloſer together, and form at laſt a fort of nu-
 “ cleus, harder than the reſt of the lens. The cryſtalline has no vi-
 “ ſible communication with its capſule, ſo that when this is opened,
 “ it readily flips out: ſome ſay, that a ſmall quantity of water is
 “ effuſed round it. Leeuwenhoek has computed that there are
 “ two thouſand laminae, or ſcales, in one cryſtalline, and that each

“ of these is made up of a single fibre, or fine thread, running this
 “ way and that, in several courses, and meeting in as many centers,
 “ and yet not interfering with, or crossing, each other.

“ The yellow colour wherewith the crystalline is more and more
 “ tinged as we advance in years, must make all objects appear more
 “ and more tinged with that colour : nor does our being insensible of
 “ any change in the colour of objects, prove to us that their colour
 “ continues the same ; for in order that we should be sensible of this
 “ change, the tincture must not only be considerable, but it must hap-
 “ pen on a sudden. In the cataract it is opaque ; the seat of this dis-
 “ order is in the crystalline lens.

“ *Vitreous Humour.*

“ The vitreous is the third humour of the eye ; it receives its name
 “ from its appearance, which is like that of melted glass. It is nei-
 “ ther so hard as the crystalline, nor so liquid as the aqueous humour ;
 “ it fills the greatest part of the eye, extending from the insertion of
 “ the optic nerve to the crystalline humour. It supports the retina,
 “ and keeps it at a proper distance for receiving and forming dis-
 “ tinct images of objects.

“ The vitreous humour is contained in a very thin pellucid membrane,
 “ and concave at its fore part, to receive the crystalline ; at this
 “ place its membrane divides into two, the one covering the cavity
 “ in which the crystalline lies, the other passing above, and covering
 “ the fore part of the crystalline, thus forming a kind of sheath for
 “ the crystalline. The fabric of the vitreous humour is cellular,
 “ the substance of it being divided by a very fine transparent mem-
 “ brane into cellules, or little membraneous compartments, con-
 “ taining a very transparent liquor.

“ *Ligamentum Ciliare.*

“ There is still one part to be described, which, though very

“ delicate and small, is of great importance ; it is called the ligamentum ciliare, because it is composed of small filaments, or fibres, not unlike the cilia, or eyelashes ; these fibres arise from the inside of the choroides, all round the circular edge, where it joins the uvea ; from whence they run upon the fore part of the vitreous humour, at that place where it divides to cover the crystalline ; those fibres are at some distance from one another, but the interstices are filled up with a dark-coloured mucus, giving it the appearance of a black membrane.

“ *Of the Figure representing the Eye.*

“ Figure 10, represents a section of the eye through the middle, by an horizontal plane passing through both eyes ; the diameter of the figure is about twice the diameter of the human eye.

“ The outermost coat, which is called *sclerotica*, is represented by the space between the two exterior circles B F B ; the more globular part, adjoining to the *sclerotica* at the points B B represented by the space between the two circles at B A B, is the *cornea*.

“ The next coat under the *sclerotica* is a membrane of less firmness, represented by the two innermost circles of B F B, and called the *choroides*.

“ Adjoining to the *choroides*, at B B, is a flat membrane, called the *uvea* : a a is the pupil, being a small hole in the *uvea*, a little nearer the nose than the middle.

“ V the *optic nerve* ; the fibres of this nerve, after their entrance into the eye, spread themselves over the *choroides*, forming a thin membrane, called the *retina*, and is represented in the figure by the thick shade contiguous to the circle B F B.

“ E E is the *crystalline* humour ; it is suspended by a muscle B b b B, called the *ligamentum ciliare*. This muscle arises behind the *uvea* at B B, where the *sclerotica* and *cornea* join together at b b, it

“ enters the capsula, and thence spreads over a great part of its
 “ anterior surface.

“ The *aqueous* humour occupies the space B A B b C b.

“ The larger space B b D b B F contains the *vitreous* humour.

“ The foregoing description, we presume, will be found sufficient
 “ to give the reader a general idea of the construction of this won-
 “ derful organ : for a fuller account we must refer him to the writers
 “ on anatomy. Enough has been exhibited to shew with what art
 “ and wisdom the eye has been constructed.”

The following is a quotation by Mr. Adams, from Reid's Inquiry into the Human Mind :

“ If we should suppose an order of beings endued with every hu-
 “ man faculty but that of sight, how incredible would it appear to
 “ such beings, accustomed only to the slow information of touch, that
 “ by the addition of an organ, consisting of a ball and socket of an
 “ inch diameter, they might be enabled, in an instant of time, without
 “ changing their place, to perceive the disposition of a whole army,
 “ the order of a battle, the figure of a magnificent palace, or all
 “ the variety of a beautiful landscape ? If a man were, by feeling, to
 “ find out the figure of the Peak of Teneriffe, or even of St. Peter's
 “ church at Rome, it would be the work of a life-time.

“ It would appear still more incredible to such beings as we have
 “ supposed, if they were informed of the discoveries which may be
 “ made by this little organ, in things far beyond the reach of any
 “ other sense. That, by means of it, we can find our way on the
 “ pathless ocean, traverse the globe of the earth, determine its size
 “ and figure, measure the planetary orbs, and make discoveries in
 “ the sphere of the fixed stars.

“ Would it not appear still more astonishing to these beings, if
 “ they should be further informed, that by means of this organ we
 “ can perceive the tempers and dispositions, the affections and pas-

" fions, of our fellow-creatures, even when they want most to
 " conceal them? that by this organ we can often perceive what is
 " strait and crooked, in the mind as well as the body : that it par-
 " ticipates of every mental emotion, the softest and most tender, as
 " well as the most violent and tumultuous : that it exhibits these
 " emotions with force, and infuses into the soul of the spectator the
 " fire and the agitation of that mind in which they originate? To
 " many mysterious things must a blind man give credit, if he will
 " believe the relations of those that see ! his faith must exceed that
 " which the poor sceptic derides as impossible, or condemns as
 " absurd.

" It is not, therefore, without reason, that the faculty of seeing is
 " looked upon as more noble than the other senses, as having some-
 " thing in it superior to sensation, as the sense of the understanding,
 " the language of intelligence. The evidence of reason is called
 " *seeing*, not feeling, smelling, tasting, ; nay, we express the man-
 " ner of the divine knowledge by *seeing*, as that kind of knowledge
 " which is most perfect in ourselves."

It is too true, that we do not, in general, know the real value of
 any blessing, until we are deprived of it ; therefore, let us hear,
 how the loss of sight is pathetically described by Milton, from his
 own feeling : In his address to the Light he says,

" I feel thy sovran vital lamp ; but thou
 " Revisit'st not these eyes, that roll in vain
 " To find thy piercing ray, and find no dawn ;
 " So thick a *drop serene hath quench'd their orbs
 " Or dim suffusion veil'd.—

* This is a literal translation of the Latin words *gutta serena*, a disease, by which the pa-
 tient is deprived of sight, though to a spectator, the eye does not appear to be injured ; because
 the seat of the disorder is in the optic nerve, and not in the ball of the eye. This was Milton's
 case.

—————“ Thus with the year
“ Seasons return, but not to me returns
“ Day, or the sweet approach of ev’n or morn,
“ Or sight of vernal bloom, or summer’s rose,
“ Or flocks, or herds, or human face divine ;
“ But cloud instead, and ever-during dark
“ Surrounds me, from the cheerful ways of men
“ Cut off, and for the book of knowledge fair
“ Presented with a universal blank
“ Of Nature’s works to me expung’d and ras’d,
“ And wisdom at one entrance quite shut out.

The Translator concludes this subject in the words of the same great Poet, as conveying a sentiment, which a wise man must deem the most effectual, if not the only real consolation under such an affliction.

“ So much the rather thou, celestial Light,
“ Shine inward, and the mind through all her powers
“ Irradiate, there plant eyes, all mist from thence
“ Purge and disperse, that I may see and tell
“ Of things invisible to mortal sight.”

Milton’s Paradise Lost, Book III.



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*On the internal formation of an Ox's Tongue; and on that of the Heart,
in Animals, Fowls, and Fish.*

A CERTAIN professional gentleman of my acquaintance, was urgent with me to examine the formation of a cat's tongue, but this I deferred from time to time, wishing rather, to investigate the nature of the human tongue, which I thought would be much more worthy of examination; by reason, that it must necessarily be provided with more muscles than the tongues of animals: for, this will appear manifest, if we consider how many various motions our tongues must exert in speaking, singing, or whistling.

Not finding an opportunity to procure an human tongue, or that of a cat, I began by examining the tongues of oxen, cutting from them small pieces, both longitudinally and transversely: and, though I thought that a complete description of the whole tongue would take up too much time and labour, I determined to give a drawing of the small muscles, and point out how they are disposed longitudinally and transversely; for, in an ox's tongue, the number of them is incredible, and in this description will be seen, not only the wonderful formation and multitude of these minute muscles, but also, we shall be fully satisfied with regard to the manner in which the tongue is sometimes extended and sometimes contracted, both in breadth and thickness.

In Plate VIII. *fig.* 11, ABCDEFGHIKLM, represents a small piece of an ox's tongue, cut off from the side, in that part where the

tongue was thickest. In this small piece are to be seen various minute muscles, cut transversely, which are represented between BCKL, and DEHI; and among these, again, there appear many exceedingly minute particles, also cut transversely, which, by reason of their smallness, could by no means be represented in the drawing, but each of them may, in fact, be considered as a muscle, for if, by the microscope, we were to dissect the before mentioned minute muscles, we should find them composed of smaller parts, like a large muscle, when dissected and viewed by the naked eye.

These fleshy muscles, thus cut transversely, constitute the substance or thickness of the tongue; and the muscles pictured at the three places in this figure, ABLM, CDIK, and EFGH, which are shewn lengthwise, extend along the tongue from end to end. And, as between the letters BCKL and DEHI, is shewn how the fleshy muscles appear, when cut transversely, so at ABLM, CDIK and EFGH may be seen their figure when cut longitudinally.

All these fleshy muscles, taken together, are not larger, when viewed by the naked eye, than the small piece or particle shewn at *fig. 12.*

I also judged it right, to take off one of these fleshy muscles, lengthwise, and to cause a drawing to be made of it, to exhibit to the eye its true formation, and also, as nearly as possible, to shew thereby, how, in the motion of the tongue, these muscles are exerted, and how they change their figure.

Fig. 13, NOPQ, represents this fleshy muscle, which I took off lengthwise, preserving the whole of its thickness, so that none of its constituent parts were broken off, except at the extremities NO and PQ: in which muscle several bendings are to be seen.

Now, supposing this muscle, placed lengthwise in the tongue, to be contracted in bendings, we must conclude, that the tongue then becomes shorter and thicker, and the muscles which lie across it, are

then perfectly straight; and, that when the animal extends its tongue, this fleshy muscle, *fig. 13, NOPQ*, and all the others which lie lengthwise in the tongue, are extended and become straight, and those muscles which lie across the tongue are then inflected or bent in like manner as represented in the former muscle at *fig. 13, NOPQ*.

When this muscle had stood three months before the microscope, it became covered with a sort of mouldiness, * which, bearing a resemblance to small flowers, I directed the limner to imitate them as nearly as possible in his drawing, and they are to be seen at *RRRRRRRR*.

The fleshy muscles, which in *fig. 11*, appear cut transversely, are, in the part lying between *BCKL*, four distinct and separate muscles, and, in the space between *DEHI*, six of the same kind, all of them distinct from each other. The parts, or spaces between them in the figure, are no other than membranes, and particles of fat, lying within those membranes. For, I never saw in such a muscle as is exhibited in *fig. 13, NOPQ*, any vein, nor any detached particle of fat, but every one of these kind of muscles, as far as I have hitherto observed, is always enveloped in a membrane, and, if the ox is a very fat one, particles of fat will be seen in the membrane.

It should be remembered, that every one of these muscles must have its tendon, or terminate in a membrane which constitutes a tendon, and not only so, but every oblong fleshy particle, of which each such muscle consists, and which appear in *fig. 13, NOPQ*, must also be provided with a tendon, or terminate in a membrane as before mentioned, and all these tendons and membranes (in my judgment) do, together, constitute that part which many take only for an inner skin, which inner skin, or rather muscular part, covering the tongue all over, is defended, as it were, by a thick external skin:

* The same appearance is noted by the author, when treating of the young plant in the Coffee-bean.

this latter skin is easily taken off when a tongue has been boiled, or has lain some time in hot water.

This disposition of the muscles in the tongue is wonderful, and the manner of their acting inconceivable by us, and still more, with regard to the human tongue, when we consider the variety of ways in which the muscles must move and turn, to produce the effect of speaking, singing, and whistling, as before observed.

The exertions of the fleshy muscles in the tongue, are chiefly produced by their assuming a straight figure, or by being inflected or bent, contrary to the manner of the fleshy muscles in other parts of the body, (as far as has come to my knowledge) for their contraction and extension, is produced by means of the multitudes of excessively minute wrinkles or crimped up particles, of which each muscle consists.

After this, I cursorily examined the tongue of an hog, to see, whether in it, the fleshy muscles were intermixed or laid one across another, in the same manner as I have described in the tongue of an ox: this I first inspected in the thickest part of the tongue, on the upper side, where it rises in a ridge like a back; and, I saw not only, that the muscles were disposed in the same manner as the ox's, but that some few of those which lay the lengthway of the tongue, in some places crossed each other; the transverse muscles were the same as in the ox's. Searching farther inward into the thickest part, I there saw many fleshy muscles lying parallel to each other, lengthways in the tongue; but no others lying athwart or crossing them. I also bestowed some investigation on the thinner parts of this tongue, without finding any thing worthy of note.

I have often employed my thoughts, on the formation of the fleshy part in the hearts of animals; not particularly to investigate the course of the fleshy muscles, which I doubt not, has been sufficiently ex-

amined and explained by others. And, though I determined, if I should observe any thing particular in that part of the subject, to commit my remarks to writing, yet, my principal object was, to investigate the formation of the very smallest fleshy muscles, and to examine whether any thing might be found therein worthy of note.

For this purpose, I took the heart of a sheep, but, with all my pains, I could not succeed in separating or taking off any fleshy muscle like that described at *fig. 13, NOPQ*, for, in the operation, it was so torn, and, so many of the adjoining parts adhered to it, that I could not then satisfy myself as to the true formation of such muscle; nor with regard to the union or connection between it and the adjoining parts.

After this, I tried the heart of an ox, cutting off many pieces, and contriving every possible means I could devise, to separate a small strip or oblong particle from the adjoining parts, but all to no purpose; and, at length, I found, that these fleshy particles were so linked together, that it would be impossible to sever them without breaking.

This concatenation, or linking together of the fleshy parts, (which parts, in treating of the tongue, I have called minute fleshy muscles) in the substance of the heart, is of such a nature, that, at first, I despaired of being able to represent it to the eye by any figure or drawing; but at length, I so far succeeded, as to exhibit a representation thereof to the reader.

In these experiments, I tried the heart of a duck, in order to see whether its formation, and particularly this union of the parts, agreed with that of an ox; and I found, that the fleshy parts in the duck's heart, were linked together in the same manner as in that of the ox; and not only so, but that I could better give a representation of such concatenation or linking, from the heart of the duck, than from any of the other subjects I had examined: and thereupon, I delivered to

the Limner a microscope, before which was placed an exceeding small piece of the fleshy part of a duck's heart, directing him to make as accurate a drawing as possible, of the object which presented itself to him.

Fig. 14, ABCDEFGHIKLM, represents this minute particle magnified, in which may plainly be seen, not only how every single fleshy particle is united or linked to the adjoining one, but also, how all the fleshy particles, shewn in this figure, are connected, chained or linked together.

As to the vacant spaces appearing in this figure, two of which may be seen at BCD, and HNI, we must not suppose, that the fleshy parts are so far asunder as the drawing represents, for I am fully persuaded, that, when the heart is in its natural state, all the fleshy particles of which it consists, are so close to each other, that nothing but an exceeding thin membrane intervenes, within which membrane the blood-vessels take their course; and there also, may sometimes be seen particles of fat, especially where the blood vessels are larger than ordinary.

Farther, I always observed, not only in the hearts of an ox and sheep, but also in that of a duck, all the fleshy particles, which, when describing them in *fig. 13*, I have called muscles, but which I cannot here call by that name, because they are not enveloped by membranes peculiar to themselves; these particles, I say, which in *fig. 14*, are exhibited at LM or AB, I found, again to consist of great numbers of slender oblong particles, which often separated from each other, and at little distances united with other particles: but these smaller particles are not represented in the figure, because they had become so dried, as not to be visible to the Engraver.

We may now figure to ourselves, that the particle of flesh, which *fig. 14*, exhibits at AB, again consists of an hundred and more oblong particles, and, that a little above AB, they are divided into four

parts, and these parts, again united with other fleshy particles. But how often this separation and reunion of parts take place, and what course the particles themselves take, I have not yet been able to discover.

Each of these several fleshy parts, of which only two are exhibited in *fig. 14*, at BCD, and HNI, were covered with broken and torn fragments of other parts, but these I directed the Limner not to delineate, that the concatenation, or the manner in which the particles are linked together, might be better distinguished.

After I had caused the before mentioned drawing, *fig. 14*, to be made, I again examined various fleshy particles in the heart of a duck, and, while I was thus employed, I met with one small piece, in which I was convinced, that the concatenation or linking together of the parts, would be still more distinctly seen. This, being placed before a microscope of somewhat less magnifying power, I delivered to the Limner to make a drawing of.

Fig. 15, ABCDEFGH, is this piece of a duck's heart, in which, more plainly than before, can be seen the nature of its formation, which will appear still more wonderful, if we consider, as the truth is, that the connection or linking together of the parts, in the particle which this *fig. 15*, represents, was, in the subject itself, thrice as much as here expressed; for, I could not separate a piece of this size from the heart, without tearing asunder twice as many parts or points of union as are here exhibited. This particle was taken from almost the outside of the heart, and, that part which in the figure is marked ABCD, was situated pointing towards the small end or tip of it.

In order to shew the true dimensions of the particle represented, in this last figure, I measured it, and found, that the whole length shewn in the figure, between the letters EFGH, was, in its natural size, not more than two third parts of the breadth or thickness of that part

which, in the figure, appears between the letters G and H, or, the size pictured at X.

Seeing now, that this fleshy particle, though not in fact, larger than the space between G and H, or at X, does yet consist of more than an hundred distinct oblong particles, as I can affirm from the most exact computation of my own view, and, that this is not only the case, in the heart of a duck, but also in that of an ox; and moreover, that each of those slender, oblong, component particles, again consists of a great number of excessively minute particles, we shall more and more be struck with wonder, at this formation of the heart. And who can tell, into how many small particles, entirely undiscoverable by us, these last named particles may be again divided?

We find, that in the common muscles of the body, those small muscular parts, which constitute a large muscle, may be separated from the larger one, often without tearing the oblong fleshy parts which compose it, nothing being broken, except the thin membrane with which the small muscular parts are, as it were, enveloped: for, all those slender, oblong, fleshy parts, lie disposed in regular parallel order, beside each other; and, at their extremities, are united to a membrane which surrounds the muscle, or, rather, forms the tendon of that muscle, which in fact the membrane does: hence we may easily comprehend, that, when any part of a common muscle is wounded, the part which remains uninjured, may still, in some degree, perform its functions; because, as I have before said, the small muscles which compose a larger one, are only connected by a kind of membrane: but, on the contrary, when any one particle in the fleshy substance of the heart, such as is represented in *fig. 15* at ABCD, or any other particle though much more minute, is wounded, the whole flesh or substance of the heart, (by reason of the intimate union of its parts) not only suffers, but, through the violent and continual agitation of the heart, in the protrusion or expelling the blood

in circulation, it becomes weaker, and, from so small a wound, death must ensue. Moreover, when I consider, how often we find a small exulceration or sore, in the hand, finger, or other part of the body, of which we cannot perhaps trace the cause, I can easily conceive, that a small exulceration may, by some accident, happen in the heart, whereby some of the fleshy particles may be injured, or rendered incapable of performing their functions; whence the heart not only languishes, and becomes feeble, but, at length, may cease to move, whence sudden death ensues: and the Physician, not knowing the real cause, is led to pronounce, according to the common opinion, that the person died of an apoplexy. These are, however, no more than my own conjectures.

From what I have advanced, it may naturally be concluded, that I shall farther lay it down as a certain position, that the heart cannot suffer any wound, without certain and immediate death being the consequence: this, however, is not my opinion, in all cases whatsoever. For, we know, that there are many veins between the fleshy parts in the inside of the heart, which take their course from thence, and unite with the blood vessels surrounding it on the outside; which blood vessels, are, throughout, and especially on the outside of the heart, covered with fatty particles; so that there may be instances, where the very extremity or point of a sword, may penetrate into the heart itself, but, being in a part where those veins and particles of fat lie, none of the fleshy particles of the heart may be injured, and the vein and fatty particles alone receive the wound, together with the external membrane surrounding the heart: hence it will follow, that sudden death may not in such a case ensue.

After this, I examined the heart of a hen, in which also, not without pleasure, I saw the concatenation or linking of the fleshy parts, to be exactly the same as in the other hearts I have mentioned.

This, however, I observed in the hen's heart, that, when cutting

it longitudinally, there appeared some difference in the formation, for, whereas the cavity in the hearts of oxen and sheep, is provided with a tendon; on the contrary, here, instead of the tendon, I found various fleshy parts, with their ramifications, spread over the cavity of it. Whereupon, I began to reflect on the great exertion, which birds are obliged to use in flying, and how little they are fatigued, even after taking a long flight. But, to say any thing satisfactorily on this head, many previous observations ought to be made.

Afterwards, I examined the heart of a cod fish, and found its component parts linked together in the same manner as I have described those of the other animals, and of the duck, to be: but when I reflected on the circulation of the blood through this heart, (which appeared more of a fleshy than a fishy nature) and considered, how the blood is propelled from it, into a white body, in solidity or density nearly equal to the heart, whose particles are linked together in the manner I have described, and to how great a degree these particles upon the infusion of the blood must be extended, and how contracted in its propulsion, I was more and more lost in admiration.



On the eye of a Whale, with the Author's observations on the pressure of the sea-water at great depths.

THE master of one of our Greenland ships, by name *Isaac van Krimpen*, upon a certain time, made me a present of the eye of a Whale, preserved in spirits of wine. This eye was not of a perfectly spherical figure, for its axis, in the thickest part, was two inches and seven-tenths of an inch in length, and the axis in the thinnest part was not longer than two inches and an half.

That part of the tunica cornea in front of the eye, which rises in a globular protuberance, was two inches and an half in diameter.

The crystalline humour was not quite of a circular figure, as we generally find it to be in fishes; but on one side, its shape was somewhat depressed, and the axis thereof measured seventeen thirtieth parts of an inch, but the axis of that part which was extended towards the object of vision, was about half an inch in length.

The cavity, wherein the crystalline humour is included, was almost two inches diameter. The substance constituting the surface of, and surrounding that cavity, was so compact and strong, that I was scarcely able to cut it with a very sharp knife.

Observing this, I began to consider, whether the nature of this fish did not require, that the substance inclosing the crystalline humour, should be so hard and solid; because a Whale sometimes dives to great depths in the ocean, and, as the fish under consideration, had run out the length of fourteen whale lines, each of which is

an hundred fathoms long; and, in this depth of sea, the pressure of water on the bottom, is much greater than is commonly imagined.

For, supposing the ocean, in any given place, to be 1400 fathoms deep, and each fathom to contain six feet, which is the common measure, it follows, that the ocean is, in such a place, 8400 feet deep.

It is well known, that a cubic foot of water, such as is found in our canals, weighs 65 pounds, but that the same quantity of sea water, being in its nature heavier, does not weigh less than $66\frac{1}{2}$ pounds; but taking it only at 66 pounds, the result will be, that every cubic foot of sea water, where the ocean is 8400 feet deep, does press on the bottom with the weight of 554,400 pounds. And, with regard to the whale lines, which I have said are 100 fathoms long, I am told that they are more commonly 120 fathoms, which gives a depth of 16,080 feet.

The same Captain Krimpen, in a subsequent conversation informed me, that this Whale, having run out the length of fourteen lines, lay on the sandy bottom of the sea at that depth, from whence it was weighed up or raised by means of the windlafs, and he added, that he should not have succeeded in getting up this fish, unless the line, which by the harpoon iron was fixed in it, had also got a turn or two round the tail, by which means, the Whale was brought up to the surface, the tail foremost.

The weighing up this Whale, was at first so difficult and laborious, that six men at least, were necessarily employed in heaving at the windlafs, and no less than six hours were spent in the operation. But, when all the lines save one, were hove in, the labour became as nothing; for which latter circumstance, I assigned to Krimpen, this twofold reason, that the pressure of the water on the Whale was then greatly diminished; and, that the fish abounding with oily or fatty parts, which are lighter than water, would have a tendency to be buoyant.

Let us now suppose, the eye of this Whale, in that part of it which was exposed to the sea water, to contain six square inches in its superficies, we may justly say, that when the fish descended to the depth of sea we have mentioned, the pressure on its eye must be equal to 23100 pounds weight. For, six square inches are the twenty-fourth part of a square foot, and, if the pressure on a square foot, at the before mentioned depth, is 554,400 pounds, it follows, that the twenty-fourth part, will sustain a pressure of 23100 pounds, which is one ton, six hundred, and a quarter of a hundred weight.

Seeing then, that six square inches of space, at the bottom of the sea, where it is 8400 feet deep, do endure a pressure of water equal to 23100 pounds weight, it is no wonder that the sea in the Bay of Biscay is not to be fathomed by the lead. For, if the sea water, at the depth we have mentioned, presses on the bottom with the weight we have computed, it follows, that in some parts of the ocean, which are at least eight times that depth, the pressure must be eight times as much.

Hence we may fairly infer, that a weight, although of lead, such as that which seamen call the deep-sea lead, cannot, where the depth is so very great, touch the bottom, or at least, not in a manner to be perceptible, not only on account of the very great pressure on the lead, but also, on account of the much greater pressure on the lead-line, by reason of its great length, which line itself is not much heavier than the sea water; so that the pressure may very naturally be supposed to prevent the lead reaching the bottom. Again, it must be considered, that the ocean, though no current may be visible on its surface, yet is never at rest; so that though the lead, when cast, seems to sink straight downwards, yet it may be carried away by some submarine current, far from the man who heaves it, and the line may be bent and twisted many ways, by all which means, in such great depths, the lead may be prevented from reaching the bottom. But to return,

The crystalline humour in this eye, was so closely joined to the tunica cornea, as to force it out into a kind of globular extuberance or rising, which appearance seemed very strange to me, having never observed the like, in any fish or animal.

I took off a piece of the tunica cornea, rather more than an inch in diameter, and, after leaving it a while to dry, I cut it by an oblique incision into slices, in order to count, with greater facility, the number of thin membranes of which it was composed, and I found, that it consisted of, at least sixteen or eighteen of those thin membranes, laid one on another.

This tunica cornea, was lined on its inside, with a black membrane, every where entirely impervious to the light, excepting an oval aperture immediately in front of the crystalline humour, through which the light was transmitted; this also was to me an unusual appearance. This oval aperture was in length half an inch, and in breadth somewhat less than a quarter of an inch.

From this last observation, a thought occurred to me, whether the whale has not a power of enlarging and contracting this aperture at pleasure, so as to alter the manner of its vision, as occasion may require. The same power of dilating and contracting the pupil, I remember to have observed in the eyes of a cat.

I then employed myself, to extract the membrane which covers the back part of the eye, and to examine the optic nerve; this I found to be no larger than the optic nerve in the eye of an ox, but I noted this singular circumstance attending it, that in many places, and I easily counted as far as twenty five of them, I saw adhering to the membrane, arteries and nerves, which issued from the part through which the optic nerve passes. Some of these, were about the size of a common pin, others much larger.

These are the matters, which appeared to me worthy of note on this occasion, though, if it were possible to obtain the eye of a Whale when

newly taken out of the head, I doubt not, that our enquiries might be prosecuted much farther, and that, consequently, greater satisfaction might be procured in the investigation.

If we consider the propagation of the Whale, by comparison with that of the smaller fish, we shall be led to admire the wise disposition of Nature in this respect. To instance in the common shrimp; every one of them may be denominated a female, for they all, without exception, propagate their species by eggs; and that, in such numbers, that once, when I began to count the eggs on one shrimp, I had not got half way through the mass of them, before I was tired, and gave up the attempt. Such a vast number of eggs, produced by one small fish is wonderful, especially if we consider, that every one of these minute eggs is nourished by a blood vessel. Now the larger fish, which devour the smaller, such as the Whale, the porpoise, and the sword fish, are not propagated by eggs, but bring forth their young perfectly formed; for if these kind of fish increased so abundantly as the others, the smaller fish would every one be devoured by them. The Whale in particular, brings forth only a single young one at a time, and is provided with two breasts filled with milk, and suckles the young, after the manner of terrestrial animals.

I have sometimes, when reflecting on the enormous bulk of those Whales which were taken at the beginning of the Whale fishery, and on those huge bones of Whales, which are in many places fixed up for public view; I have, I say, on these occasions, conjectured, that probably those Whales might be of the age of a thousand years and upwards. For I am persuaded, that fishes never die of old age, forasmuch as their bones, being always of a soft texture, which never grows hard, may always be extended, so that the fish themselves are always growing larger. But, terrestrial animals are exposed to the changes of the atmosphere, whereby their bones grow hard, and

when the bones are hardened, the body of the creature cannot be extended to a larger size.

Having once, with the assistance of an able geometrician, and by the eye with the help of quadrants, measured the height of the tower of our new church in Delft, we found it to be 299 feet.* So that the depth of the sea, to which the Whale I have mentioned descended, was twenty-six times as much as the height of that tower.

* The London reader will be better able to judge of these altitudes, (the word *altitude* taken in the sense of the Latin, *altitudo*, from which it is derived, signifies both height and depth) by comparing them with the Church of St. Paul's or the Monument: the former of these is about 500 feet in height, and the latter 200; so that if we call the height of the steeple at Delft 300 feet, the Church of St. Paul's is two thirds higher, and the Monument one third lower than that steeple. And the depth of sea from whence the Whale was raised, was equal to forty-two times the height of the Monument, and more than sixteen times the height of St. Paul's.



(272)

*Of the Quills used in writing, and their feathers : on human hair, and
the hair and wool of animals.*

MY reflections on the nature of those Quills with which we write, as also on the general make of the feathers of birds, led me to an inquiry into the manner of their formation ; which at length I discovered, and found, that Quills are composed of streaks, or more properly speaking, vessels. These vessels, in every Quill, are three-fold. The first, or external ones, which constitute but a small part of the Quill, are parallel to its length: the second, which are in a much larger quantity, take their course round about the Quill, within the former ones : these second sort of vessels are not so closely united as to form what may be likened to a solid body, but lie one on another like scales or coats, in such manner, that the different layers of them may be plainly perceived : the third sort of vessels, which compose the thickest or greatest part of the Quill, lie lengthwise, in like manner as the first mentioned ones : this third sort of vessels, are also disposed in the manner of scaly parts laid one on another ; and, considering the thinness of a Quill, and the large cavity it contains, its formation is, in my judgment, the most perfect that could be contrived ; for, hereby it is made tough and strong, both in its circumference, and in its length. To exhibit the nature of it to the eye, I caused a drawing to be made of one.

In Plate IX. *fig.* 1, ABCDEFG, represents a common goose

L 1

Quill, drawn smaller than the natural size. At A B G, are represented those vessels which compose the external part of the Quill, and lie in it longitudinally; B C F G, are those which take their course round about it; C D E F, are the vessels, which, like the first mentioned ones, are placed the length way of the Quill.

From these observations, I discovered the reason, why some Quills when they are split lengthwise, in that part where they are hardest, form a kind of indented or jagged part in the fissure;* namely, because those vessels, whose course is round the Quill, are not all broken in an even straight line; especially, as I said before, where the Quill is hardest: and where these vessels are heaped together in greater quantities than in other parts. Therefore, to prevent this accident, when the Quill is so very hard, it is necessary to scrape it a little with the pen knife, by which means, in the splitting, it will be straight and even.

I have frequently, by the microscope, contemplated that part of these Quills which is called the feather, and also the feathers of small birds; and always viewed them with admiration; not only on account of the multitude of parts to be seen in them, but also, by reason of the great numbers, and extreme minuteness of the vessels, of which, not only the whole feather, but every little part of it is composed.

To exhibit to the view, the great numbers of vessels of which the feather consists, I placed a small piece of one before a microscope, and a drawing of it is given at *fig. 2*, L M N O P Q.

In the preceding *fig. 1*, D H I K E exhibits part of the feather of the common writing Quill, smaller, as before observed, than the natural size. At K, is represented a small part of the feather, a piece of which, seen by the microscope, is shewn at *fig. 2*, for, if the whole

* This most commonly happens in those Quills which have not been, what is called clarified, or when the Quill is split near the feather; this jagged shape of the split is well known to school boys, and is denominated by them, cats teeth.

of this piece were to be drawn when magnified, it would appear larger than the whole feather, seen by the naked eye. When this small part of the feather is viewed by the microscope, it will appear, how every one of its parts consists of a great number of smaller feather shaped parts, all which parts are so connected or knit together, as to give strength to the whole feather.

The reader, here, must understand, that the particle or piece which is shewn magnified at *fig. 2*, LMNOPQ, is not, in fact, so big as a large grain of sand: and further, that this particle received nourishment in its growth, no otherwise than by small vessels: the reader also will advert to *fig. 3*, RS, which is drawn from a microscope of greater magnifying power, and is stripped off from the side of *fig. 2*, at MNO, and also to *fig. 4*, TV, which is taken from the side of *fig. 2*, at QPO.

At LMQ, is represented a part, bearing the appearance of globules, of which the interior substance of this small particle of a feather is composed, which agrees with the formation of the corresponding part in the entire feather of the Quill, pictured at *fig. 1*.

In the figures 3 and 4, by R and T, are represented some small vessels broken or torn asunder.

All these small particles, each of which may be called a minute feather, not only serve to give strength to the whole feather, but are so contrived, that in the bird's flight, these particles remain so closely joined together, as to enable it to make a strong impression on the particles of air, by the exact and regular order of the component parts of the feathers. For otherwise, birds would not be able to support themselves in the air. All these particles, as I said before, lie in most exact order beside each other, which has induced me frequently to contemplate them, as also on account of the innumerable multitudes of vessels of which the Quill consists.

From this instance, in the formation of the feathers of birds, we

may observe, that provident Nature, if not in all, at least in many things which come under our investigation, performs her operations with the greatest uniformity ; for, in like manner, the crystalline humour of the eyes, not only of men, but of the larger terrestrial animals, and also of fishes, as far as I have examined into them, consists of a kind of scaly parts, laid one on another : so likewise the tunica cornea or horny coat of the eye, which coat, I at first conceived to be composed of only three distinct membranes, but afterwards, on a more accurate investigation, I found to consist of an hundred membranes, laid one on another like scales. And I conclude that this formation is designed, not only to give the coats of the eye a great degree of strength and firmness, but also, that if one of the membranes should be hurt, the others may escape uninjured.

It is the opinion of many, that the hairs on the bodies of men and animals, are hollow, and some think, that they contain in them a marrow like the bones ; but these opinions are erroneous. Hairs are formed with a kind of coat, which is analogous to the bark of trees, and their internal substance consists of streaks or fibres. Their growth, is not like that of plants, but is produced by a kind of propulsion, that is to say, that the part which one day is within the skin, and is as it were, the root, in a day or two, is thrust out beyond the skin : and as, when the hair first comes forth, it is, in all its parts, very moist, as soon as the moisture begins to evaporate, the coat or bark of the hair, and the fibres adjacent to it, acquire a degree of firmness which prevents the hair from contracting inwards, whence it comes to pass, that, as the internal fibres continue to dry, and thereby become thinner, they are divided asunder, and recede from each other, sometimes forming one, and sometimes more chinks, exhibiting a kind of darkish furrow or furrows, which,

doubtless, is what has been taken for the marrow of the hair. All this will be better understood from the following figures.

Fig. 5, ABCD, is a piece of an hog's bristle, which I cut by a transverse section; EEEE, are the chinks or cracks, arising from the drying of the hair as above mentioned, and this hair is burst or cracked, in the inside, more than ordinary. *Fig. 6*, FGHI, is a piece of the same hair, somewhat nearer the skin, also cut transversely, in which, there are not many cracks, or chinks, but only one, which is, however, so large, as to exhibit the appearance of a hole or cavity in the hair, as appears at KLM, and any one, upon seeing such an hair as this, would certainly conclude, that the cavity here seen, was not accidental, but the natural form and make, and consequently, that all hairs are hollow. *Fig. 7*, NOPQ, is another piece of an hog's bristle cut transversely, from which I suppose the moisture had evaporated so slowly, as not to leave the least appearance of a chink or crack: *fig. 8*, is a perfectly black hog's bristle cut transversely, and, as it exhibited a pretty appearance, I have given a drawing of it. And, though the roughness, which is on the edge of the sharpest razor, frequently leaves scratches on the face of the hairs thus cut transversely, I almost wholly avoided that appearance, for which reason, I was better able to point out the streaks or fibres of which the hairs consist.

From the preceding figures, it will appear, how much those are mistaken, who will have it, that all hairs are round, whereas we ought rather to say, that every hair has a figure peculiar to itself.

It is my opinion, that the hairs on man's body, do, at certain seasons, fall off, and are again renewed, like the feathers on birds; at least, I have experienced this to be the case with myself every spring, (excepting the hairs on my head and beard) and I have observed, that those hairs which seemed ready to fall off, could be pulled out with a small pair of pincers, and not cause that pain which attends

the plucking out a hair that is firmly fixed; and I have farther observed, that those hairs which are pulled out by force, have large thick roots, whereas, the roots of those which are near falling off, are very small and pointed.

Fig. 9, ABCDEFG, and HLMNPQ, are two very small human hairs with their roots; in these will be seen, that the points or small ends of them, at G and Q, are somewhat bent, which I attribute to this, that the points, when thin and tender at their first expulsion from the skin, had met with some obstacle in their growth, which not being able to penetrate, they were bent obliquely: It is not usual to see hairs bent at the small end, in the manner shewn at G, but they most commonly appear as at Q.

AB, and HL, are the roots of these hairs, which do not appear so large, if the hair falls off of itself, but, when a hair is pulled out by force, the root appears much larger than the hair itself, as is shewn in this figure.

The bending of the hairs I have noted above, may very easily be occasioned by their meeting with some obstruction in their growth, and having observed a hair on my arm, which was very much bent, I pulled it out, and placed it before a microscope, in order to shew its figure in a drawing.

Fig. 10, ABCDEFGHI, exhibits this hair, in which, ABC is the root, and at AC may be seen a small portion of the cuticle or outer skin, which adhered to the hair. DEF, indicate a considerable bending in the hair, and at GEH is shewn a much greater bending, or rather, an entire circular curve.

I have said, that hairs are covered with a coat or bark, in like manner as trees, and that, however small, they are composed on the inside of oblong parts or fibres, and I am persuaded, that there is no difference between sheep's wool, which is the smallest kind of hair, and the hairs of men and animals, except, that sheep's wool consists

of a less number of internal fibres. In order to satisfy myself in this respect, I often broke pieces of wool, and endeavoured to split them into smaller parts, wherein at first I was unsuccessful, but at length I found means, not only, distinctly to see this formation myself, but also to exhibit the same to the view of others.

I therefore delivered to the Limner three microscopes, directing him, to make drawings of the objects he saw.

Fig. 11, KLMN, represents a small piece of white sheep's wool, in which, at *L* and *M* may be seen, that it consists of a great number of smaller hairs, (if we may call the interior parts of the wool by that name;) and who can tell, whether each of the particles, shewn at *LM*, may not again consist of a great number of still smaller particles?

This piece of white sheep's wool, was very transparent before it was broken, or cracked; but, at *L* and *M*, where many of its oblong component particles are broken or severed asunder, it appeared quite opaque, and more of a black colour than transparent.

Fig. 12, OPQ, represents a piece of white wool, placed before another microscope; this piece is broken or burst open only in one place, where alone the internal parts appear, and at *Q* only two of those internal parts can be seen, whereas, in the piece pictured at *fig. 11*, all the internal fibres are divided asunder.

Observing one of the hairs on my arm, to be not only much broken or worn away, by the friction of my shirt, but also the internal parts to be separated from each other, I pulled out the hair, and placed it before a microscope: this piece of broken hair, magnified, is represented at *fig. 13, RS*, wherein at *S*, which is the part worn or fretted away, some smaller particles appear, being the small fibres of which the hair consists.

The preceding experiments and observations, will, I trust, refute the erroneous opinion I have mentioned, that the hairs on our bodies

are hollow within, and, if hair and wool, (which is the hair of sheep) were not composed of many minute hairs or fibres, they would not have that strength and toughness which we observe in them.

Sometimes, in human hairs, and especially in the very middle of them, I have observed a dark line: particularly in several of the hairs taken from my own beard: and when I attentively examined this dark line, I found it to consist of such minute and slender particles, as to be almost undiscoverable even by the microscope. Examining some very small hairs, of three, four or five days growth, and finding some to be throughout quite transparent, others darkened only in a very small degree, and finally, others with no more than a small dark spot on them, I began to consider, whether this dark shade in the hairs, might not proceed from some particles of blood in the substance of the hair, and there dried.

To give the reader an idea of this dark line, I caused a drawing to be made of a piece of a single hair, which I concluded to be of three days growth; this is to be seen at *fig. 14*, OPQRSTVW, in which at QRS and VW O, are the two ends where the piece of hair was cut with a knife: from W to P, or as far as T, the dark line I have mentioned extends, which I have mentioned to be visible in some hairs, and in others not so conspicuous. Lastly, between R and T P are represented those dark spots, which are to be observed in other hairs.



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THE TRANSLATOR, TO THE READER.

IF this translation is a faithful one, I doubt not that the Reader will be led to admire the extensive range of the Author's researches, and the pains he takes to make his discoveries intelligible to all; and those who compare his descriptions with the productions of Nature at this day, will be equally pleased to observe their exact coincidence.

But, though I think it may fairly be said, that the works of Mr. Leeuwenhoek are, upon the whole, superior to any that have appeared upon Microscopical subjects, I do not mean to say, that there are no instances, in which others have not been equally successful. A countryman of our own, Dr. Robert Hooke, who was a cotemporary of the Author, and Secretary to the Royal Society soon after its first institution, published several Essays, containing his discoveries by the Microscope, with many very judicious and useful remarks. In some of these, Dr. Hooke has handled the same subjects as our Author, and I shall take occasion, here to introduce a passage from that Book, wherein some of the particulars respecting Feathers, mentioned in the preceding Essay, are more minutely described than by Mr. Leeuwenhoek. *

“ Examining several sorts of Feathers, I took notice of these particulars in all sorts of wing-Feathers, especially in those which served for the beating of the air in the action of flying.

“ That the outward surface of the Quill and stem was of a very hard, stiff, and horny substance, which is obvious enough, and that the part above the quill was filled with a very white and light pith, and, with the microscope, I found this pith to be nothing else but a kind of natural *congeries* of small bubbles, the films of

* Hooke's Micrographia, p. 165, Edit. 1667.

“ which seem to be of the same substance with that of the quill, that
 “ is, a stiff transparent horny substance.

“ As for the make and contexture of the down itself, it is indeed
 “ very rare and admirable, and such as I can hardly believe, that
 “ the like is to be discovered in any other body in the world; for
 “ there is hardly a large Feather in the wing of a bird, but contains
 “ near a million of distinct parts, and every one of them shaped in
 “ a most regular and admirable form, adapted to a particular design:
 “ for, examining a middle sized goose quill, I easily enough found
 “ with my naked eye, that the main stem of it contained about 300
 “ longer and more downy branchings upon one side, and as many on
 “ the other of more stiff but somewhat shorter branchings. Many
 “ of these long and downy branchings, examined with an or-
 “ dinary microscope, I found divers of them to contain near 1200
 “ small leaves, (as I may call them) such as EF in the figure*
 “ and as many stalks: on the other side, such as IK in the same
 “ figure, each of the leaves or branchings, EF, seemed to be di-
 “ vided into about sixteen or eighteen small joints, as may be seen
 “ plainly enough in the figure, out of most of which there seemed
 “ to grow small long fibres, such as are expressed in the figure, each
 “ of them very proportionably shaped according to its position, or
 “ placed on the stalk EF; those on the under side of it, namely,
 “ 1, 2, 3, 4, 5, 6, 7, 8, 9, &c. being much longer than those directly op-
 “ posite to them on the upper; and divers of them, such as 2, 3, 4, 5,
 “ 6, 7, 8, 9, &c. were terminated with small crooks, much resem-
 “ bling those small crooks, which are visible enough to the naked
 “ eye, in the seed-buttons of burdocks. The stalks likewise, IK, on
 “ the other side, seemed divided into near as many small knotted
 “ joints, but without any appearance of strings or crooks, each of
 “ them about the middle K, seemed divided into two parts by a kind

* Plate IX. fig. 15.

“ of fork, one side of which, namely, K L, was extended near the
 “ length of K I, the other, M, was very short.

“ The transverse sections of the stems of these branchings, mani-
 “ fested the shape or figure of it to be much like INOE, which con-
 “ sisted of a horny skin or covering, and a white seemingly frothy
 “ pith, much like the make of the main stem of a Feather.

“ The stems of the downy branches INOE, being ranged in the
 “ order visible enough to the naked eye, at the distance of I F, or
 “ somewhat more, the collateral stalks and leaves (if I may so call
 “ those bodies I newly described) are so ranged, that the leaves or
 “ hairy stalks of the one side lie at top, or are incumbent on the
 “ stalks of the other, and cross each other, much after the
 “ manner expressed in the figure, * by which means every one of
 “ those little hooked fibres of the leaved stalk gets between the
 “ naked stalks, and the stalks being full of knots, and a pretty
 “ way disjoined, so that the fibres can easily get between them,
 “ the two parts are so closely and admirably woven together,
 “ that it is able to impede, for the greatest part, the transcurfion of
 “ the air ; and though they are so exceedingly small, as that the
 “ thickness of one of these stalks amounts not to a 500th part of an
 “ inch, yet do they compose so strong a texture, as, notwithstanding
 “ the exceeding quick and violent beating of them against the air, by
 “ the strength of the bird's wing, they firmly hold together. And it
 “ argues an admirable providence of Nature in the contrivance and
 “ fabrick of them ; for their texture is such, that though by any ex-
 “ ternal injury the parts of them are violently disjoined, so as that
 “ the leaves and stalks touch not one another, and consequenti-
 “ veral of these rents would impede the bird's flying ; yet, for the
 “ most part, of themselves they readily re-join and re-context them-

* Plate IX. fig. 16.

“ felves, and are easily by the birds stroking the Feather, or drawing it through its bill, all of them settled and woven into their former and natural posture ; for there are such an infinite company of these small fibres in the under side of the leaves, and most of them have such little crooks at their ends, that they readily catch and hold the stalks they touch.”

Here we see a perfect agreement between these two valuable writers, in describing the same subject, with this difference only, that the English author has more minutely described that curious part in Feathers, which Mr. Leeuwenhoek only mentioned slightly ; I mean the contrivance of Nature, whereby the several minute Feathers composing the larger, are knit together so firmly as to bear the strong exertion of the bird in flying, without yielding a passage to the air.

The same Author, in treating of hair, has these words, “ The root of the hair was pretty smooth, tapering inwards, almost like a parsnip, nor could I find that it had any filaments, or any other vessels, such as the fibres of plants.

“ The top when split (which is common in long hair) appeared like the end of a stick, beaten till it be all flattered, there being, not only two splinters, but sometimes half a score and more.

“ For the bristles of a hog, I found them to be, first, a hard transparent horny substance, without the least appearance of pores or holes in it, and this I tried with the greatest care I was able, cutting many of them with a very sharp razor, so that they appeared, even in the glass, to have a pretty smooth surface, but somewhat waved by the sawing to and fro of the razor, as is visible in the end of the prismatical body A in the figure.* The shape of the bristles was very various, neither perfectly round, nor sharp edged, but prismatical, with divers sides, and round angles as appears in the same figure. †

* Micrographia, p. 157. † Plate IX. fig. 17.

An extraordinary quantity of Fish on the sea coast near Delft, noted by the Author, with the reasons assigned by him for the same.

IN the months of April and May 1716, there were brought to our town of Delft, from the sea coasts at Schevling, Catwick, and Terheid, a great quantity of the fish called haddocks, which, though very fresh and good, were sold at a low price. The glut of this fish was so great, that though in general they are caught with hooks, they were on this occasion, taken in nets.

Seeing this, I considered, that there must be some particular reason, why these fish should at that time resort to our coasts in such multitudes, and I was afterwards confirmed in that opinion, for in a month or two afterwards, not one of those fish was to be taken: and the reason which I assigned to myself for the abundance I have mentioned was, that at that time, there was a greater quantity of food for them on the coast than usual, whereby they had been tempted thither.

In order to investigate this matter, I opened the stomachs of many haddocks, and found them to be filled with a certain small species of shrimps, called by our fishermen meutjens, which are taken among the common shrimps, and are used for food by people living along the shore.

About a fortnight afterwards, on examining the stomachs of the haddocks, I found some of them quite empty, and others not more

than half filled with the before mentioned small fish ; and so much was the glut then diminished, that few or no haddocks were taken. Upon enquiring the reason of this diminution from a fisherman, he answered only, that every sort of fish had its season, though I should rather have said, in the words of scripture, "that where the food is, there will the eagles be gathered together."

At the time there was this glut of haddocks, there was a great quantity of cod fish caught on our coast, the reason of which I took to be, that these cod flocked to our shores in pursuit of the haddocks which are their food.

About the beginning of October, in the same year, there were taken on our coasts, great quantities of the common shrimps, and those in better condition than they are generally found in the summer time. Hence I concluded, that the haddocks would again resort to our coasts, and that the shrimps, to avoid them, would crowd in greater quantities to the shores and shallows.

To satisfy myself in this respect, and that I might learn what particular kind of food is used by the haddock, I caused the entrails of a very large one to be brought to my house ; but, to my great surprize, I found not only the stomach, but the intestines adjoining it, to be entirely empty of food.

I enquired of a fishwoman what might be the reason of this, who gave me the following answer: Our fishermen (for she lived at Delftshaven) have a pond or cistern, lined at the bottom and on the sides with timber full of holes, so that the water freely passes in and out with the tide ; and the fish being kept in this cistern, can at all times be brought to market alive and vigorous. But the fishermen say, that when the haddocks are thrown into this cistern, they immediately empty their stomachs of all the food they have swallowed.

Hereupon, I examined a little of the matter or substance contained

in the intestines at a considerable distance from the stomach, and I found the same to consist of fragments of shrimps mixed with many particles of sand, rather larger than the sand found on the sea shore, and which particles of sand I concluded the haddock had picked up with the shrimps from the bottom of the sea, and had swallowed down both together. Among these grains of sand, I saw many shining particles; some thousands of which, laid together in an heap, would not equal a large grain of sand: these were all of different shapes, but, in every one of them, the sides, angles and points, were so smooth and glittering, as to be very little inferior in beauty to the most polished diamonds. At first, I supposed them to be no other than common salt, but I found them to be much more hard and solid than our salt. After I had steeped them a short time in rain water, I could still distinguish some of them, though much diminished in brightness; others of them, seemed to be partly dissolved, and to be surrounded with smaller particles: these latter, I concluded to be, still more minute salts, which, in dissolving, had separated from the larger ones, and afterwards concreted in clusters.

In the month of November in the same year, there was another great draught of haddocks on our coast, whereupon I went to the fish market to examine the intestines, when newly taken out of the fish: I found most of the stomachs to be empty of food, but some remains thereof in the intestines; and, as at the same time, great plenty of cod fish were caught, I judged that the haddocks, avoiding the pursuit of the cod, and these pursuing the haddocks, was the reason, that both were taken in such abundance.

Those persons, who are very nice in their taste, prefer the haddocks brought to us from Maeslandfluys, to those that are brought straight from the sea shore, though both are taken near the same tract in the ocean. Upon considering with myself, what might be the reason of this difference, I could not assign any more probable

one than this, that those haddocks which are brought straight from the sea side, are, as soon as taken, thrown into baskets, to the number of eight or ten in each basket, and die, thus heaped together, before they are exposed to sale: whereas, the fishermen at Maeflandsluys, keep their fish for a time in those cisterns I have described; and the fishermen of Delfthaven, have also a kind of fish trunk or well in their boats for the like purpose. Therefore, the fish which are thus kept alive without food for two or three days after they are caught, are of a much better taste.

The same is experienced in river fish, especially trout, which, when caught in the summer time, are unpleasant to the palate, tasting of the herbs on which they feed, but, if kept a few days in stew ponds, cisterns, or other fit receptacles, are much improved in flavour.

But to return to the subject of the fish market, I observed a large cod fish, very much distended with a quantity of food, namely, haddocks, which it had devoured, when some of the smaller cod lying near it, appeared empty. Hereupon, I enquired of an old fisherman, whether those cod fish, which were so distended, did not differ in taste from those, whose stomachs were empty; to which he answered, that those cod were to be preferred, whose bellies were compact or close. This is a phrase among fishermen, applied to those fish whose roes are not very large, and whose stomachs are very little, or not at all distended with food.



Of the Nutmeg; the young plant in it discovered; the root of the Nutmeg-tree examined and described; with some hints from the Author respecting the best method of preserving Nutmegs from being injured by insects.

HAVING, at many different times, employed myself in the examination of Nutmegs, in order, if possible, to discover the young plant of the future tree (which, I was well assured they contained) but always without success, I at length received, from one of the Directors of the East India Company, residing in our town, a few Nutmegs, and also a parcel of powder or dusty matter, which had been found adhering to some of the nuts*, to the intent, that I might examine them, and see whether this powder had not been gnawed or bitten off the nuts by mites.

With the greatest accuracy I was able, I examined this dusty matter, and, with all my attention, I could not discover in it any mite either alive or dead, but in some of the Nutmegs which had been in part eaten away, I found several small maggots of different kinds, and also a few flying insects which I concluded had been bred from maggots of the same species; but the bodies of all these creatures were so much shrivelled, that I concluded they had been long dead, and that, not being natives of these regions, they could not endure the cold of our climate.

* This valuable fruit or spice, which, in English, is called by the single word Nutmeg, is in Dutch denominated Noot Muscaat, herein agreeing with the botanical Latin name *Nux moschata*, the Musk-nut; it is also denominated *Nux myristica*, the odoriferous or sweet-smelling nut.

I next went to our East India Company's warehouse, at the time the officers employed to sort the spices were busy in allotting the Nutmegs according to their qualities, and I brought home with me, two or three handfuls of the refuse thrown away: any one upon viewing this with the naked eye, would easily be led to conclude, that it contained mites, but with my utmost attention, I could not discover any mites, much less their eggs, and only a few of the dead insects I have before mentioned. I also brought home ten or twelve of the most damaged Nutmegs, which felt very light in the hand, and were much shrivelled: upon examining these carefully, I found that most part of the dust or powder, which upon a cursory view might be taken for mites, was nothing else than the dust of the Nutmegs, and the excrements of maggots which had almost entirely scooped out the insides of those nuts.

In the examination of these and other Nutmegs, it appeared to me, that those which had been gathered unripe, were the most liable to be devoured by maggots, because the oily matter in this nut, which pervades its substance in streaks like the veins of marble, and covers the outward bark in like manner, is contrary to the nature of these maggots; for when I cut open the nuts wherein they were, I found the oily part every where uninjured, and on the contrary, all the whitish part of the nut consumed, so that those oily parts lay within the nut, exhibiting to me, as it were, a labyrinth of turnings and windings, whereas, the unripe nuts, where the oily substance was not completely formed, were in the insides, quite consumed; I also perceived the external coat of the ripe nuts in some places bored or eaten through, but in my opinion, when the maggots reached the parts where the oil was fully ripened, they desisted from farther biting, and only devoured that part where the young plant is situated, and which is the thickest part of the nut.

I was much surprised, that I could not discover any mites among

the Nutmegs, because there is rarely any substance that can be used for food, where they are not to be found.

I determined therefore, to examine whether mites fed upon the Nutmeg, and therefore I placed about a quarter of a nut, among a parcel of mites, when I perceived that they fled from it.

Moreover, I took a glass tube, somewhat larger than a swan's quill, one end of which I stopped with a cork, and, after putting into the glass some hundreds of mites, I cut a small piece of Nutmeg of a size that I could put it into the tube; and I perceived that the mites next the Nutmeg soon died. I then put another piece at the other extremity of the tube where there were many live mites, which also in a very short time died.

To satisfy myself still farther, I took a glass tube, thirteen inches long, and half an inch diameter; one end of this I closed by melting it, and put as many mites into it as I computed in bulk altogether to be equal to half a cubic inch, and, according to the exactest computation I could make, they were in number 150,000.

After these mites had been about a quarter of an hour in the tube, they spread themselves from the mass in which they were, when first put in, and dispersed all over the glass; I then split a very sound and good Nutmeg into four parts, one of which parts I placed in the open end of the glass, so that I might observe by the microscope, what effect it would have on the mites when they approached it.

Most of them I saw creeping towards the open end of the tube, and when they came to within about a straw's breadth of that part where the piece of nut touched the glass by two of its points, many of them returned back, though they might have passed by the nut without approaching nearer than the eighth part of an inch to the main substance of it.

The retreat (so to express myself) of these multitudes of mites, afforded me a very pleasant spectacle, for here it appeared, that the exhalation or vapour proceeding from the piece of Nutmeg, was so

noxious and offensive to them, that they drew back from it faster than they had advanced towards it, in order to make their escape out of the glass.

Some others of the mites having advanced so far as to have got some hairs breadth distance beyond the Nutmeg, were presently arrested in their course, and, losing all motion, they expired.

Moreover, I observed numbers of the mites creeping along the glass, near that part of the Nutmeg which was covered with the rind, and they would have escaped, if I had not intercepted them by placing another piece in the way, so that they could not get out without passing the broken part of the nut, and hence it appeared to me, that the vapour of the nut exhaled much more feebly next the rind, than from the internal newly broken part. Hereby, not only the escape of these mites was prevented, but all that were near the nut died there, and in the space of eight and forty hours, out of so great a number of mites very few were left alive.

To explain this experiment better, I caused a drawing to be made of the glass tube I used on the occasion, which is to be seen in Plate X, *fig. 1*, ABCDEFGHI. Here, AI is the open end of the tube; E, the end which was closed, and in which the mites, when first put into the tube, lay in the greatest numbers. Between CD and FG, was placed the first quarter of the Nutmeg with the internal broken part next the eye, where some of the mites had crept on the other side of the glass next the rind, and passed by the nut, when as I mentioned before, I placed the other piece of nut, with its broken side the contrary way to the other, so that the rind appears between AB and HI next the eye, by which the mites were prevented from escaping, and all died within the glass.

In reflecting on the circumstance of these mites being thus killed, I judged that it was not by the vapour of the Nutmeg being hurtful

to their bodies in general, such as the skin, bones, &c. but that it acted so powerfully on the lungs of those creatures, as to prevent their respiration. For, in like manner as noxious vapours do not, so far as I know, in any manner injure our skins, because the moisture of our bodies is continually expelled from the inward parts outwards, through the skin to the surface; and as no particles, either of foul air or common water can be received into the body through the skin, for which reason it is, that the fleshy parts of fish or other animals, living in water, however salt it be, do not partake of that saltiness; so mites, the same as larger animals, who are kept alive by respiration, die when that respiration is obstructed or prevented. And if so, we have here another instance of the surprising order and regularity with which all things are created, shewn in the wonderful formation of the mite, which, though unknown to many persons, and, by reason of its minuteness, held of no account, does yet appear to me, endowed with greater perfection, and more curiously formed than many larger animals.

After the preceding observations, our East India Fleet arrived, whereupon, I became desirous to procure some of the Nutmegs newly imported, and those of the best and ripest; in order, that if possible, I might so far cause them to vegetate, that I might be convinced I saw the young plant in the nut, and might also be able to take it out from thence. And one of our East India Directors very kindly gave me some of the largest Nutmegs; among these I perceived a few, which, though thoroughly ripe, were infested with maggots.

Two of these nuts I opened, and out of each I took a thick short white maggot, about the fifteenth part of an inch in length, furnished with six feet in the fore part of its body, and covered with a great number of long and very slender hairs: from the same nuts I also took two or three pellicles or thin skins of different sizes, which appa-

rently had belonged to maggots of the same species, whence I concluded, that during their growth, these maggots change their skins in like manner as silk worms are observed to do.

I also found in these nuts, two flying insects of different kinds, but they, as well as the maggots, notwithstanding all the care I could take, soon died, whence I was more convinced that the maggots which feed on the Nutmeg are not natives of these regions, and I do not doubt, that if the warehouses in India, where Nutmegs are kept, were to be well fumigated with sulphur, once a month, (for if this is done only once, those insects which are at that time alive may be killed, but the minute maggots inclosed in the eggs will escape unhurt, and therefore the fumigation must be repeated) by this operation the Nutmegs would, in a great measure, be preserved from damage. And I also think, that it would be very proper to fumigate the holds of the ships with sulphur, by which means these maggots, and those whose nature it is to perforate and feed on timber; also, the insects called cock roaches, the millepedes, or thousand legs, and even mice, which hide themselves in the holds of ships, must be all destroyed.

I endeavoured, three several times, to cause the Nutmeg to vegetate, but I had not the good fortune to succeed; which, I think, was partly owing to the lime with which the nuts had been sprinkled, and partly to their being so much dried, that in many places they were cracked in the inside. In this my search, however, after dissecting many nuts, I at length, with great pleasure, not only discovered the plant, but succeeded in taking it out of the nut. The outer part of the leaves of this plant was formed with many indentings and points in the manner of vine leaves, and the leaves themselves were as large as I ever found in the seed of any tree whatever. Upon viewing these leaves by the microscope, I could see the veins or vessels, lying in as regular order, as are to be seen by the naked eye in the full grown leaf of any tree.

Fig. 2, KLMN, represents this small plant taken out of the Nutmeg, as nearly as the limner was able to draw it from the naked eye; and though it seems to be composed of many leaves, yet, in my judgment, there are but two; but I could not examine that matter very accurately, because in the attempt, the plant was often broken. The part in this figure marked *N* is that, from whence the stem and root would grow.

Moreover, I placed a small piece of the outward part of this leaf before a microscope, and directed the limner to make a drawing of it with all the vessels in it, as they appeared to him.

Fig. 3, OPQRS, represents this piece of leaf; *OP*, is the part which was broken off from the rest of the leaf, and *QR* is the external edge of it.

In this small piece of leaf we not only see, how the vessels or veins are branched out into smaller ramifications, but in many places may plainly be seen, the oily matter or substance, which is the same in nature and colour, as is to be seen in the nut itself. And since we see so many branchings of the veins in so small a piece of a leaf, who can tell how many more ramifications there may be in it, entirely escaping our sight?

During the time that I was employed in searching for the plant in the Nutmeg, I fell into conversation with a friend respecting the tree that bears this fruit, which tree, I was persuaded, had some cavity in the middle of it; this coming to the ears of a certain Professor, he sent me two pieces of the root of the Nutmeg tree.

Upon examining those pieces of root, both at the larger and smaller ends, I was greatly surprized to find, that this wood is of a remarkably spongy nature and very porous, though it has not any cavity in it, different from the wood of other trees; for, from the root, we must conclude, that the tree itself is of the like formation.

And in this root, I perceived some wonderfully minute vessels, furrounding, as it in were, many places, the larger tubes of the wood, and through which, as I suppose, the tree receives nourishment in its growth.

In order, as exactly as possible, to exhibit to view the wood, or rather the root of the Nutmeg-tree, which bears such a precious and highly valued fruit, I have given the figure of a circle, which we must suppose to be a branch of the tree, or of its root, sawed off transversely, as is to be seen at *fig. 4*, ABCDEF. From the center of this figure are drawn many very small lines, as appears between CDF A, and these we are to suppose are those vessels which serve for the increase of the tree or root, and, by means of which, there is every year a new substance formed about the tree, as I have often heretofore mentioned.

Now, in order to investigate accurately, the true formation of this wood, we must not examine merely the extremity of it, which would present an obscure object to the eye, but we must cut off a small piece or particle of the wood, as from E to the circumference, after we have, with a very thin and sharp knife, cut or pared the extremity as smooth as possible. In this manner I cut off a piece or particle of the wood, not so large as is shewn at *fig. 5*. This piece of wood, placed before the microscope, and copied as exactly as the limner was able to represent it in his drawing, is shewn at *fig. 6*, ABCDEFGH, and in it are to be seen, many of the vessels or tubes of which the wood consists, some of the larger ones of which, I have exhibited at I, I, I.

Among these larger tubes of the wood are to be seen a great number of smaller ones, and many of these smaller tubes are again furrounded by other excessively minute vessels, through which latter vessels, for the most part, the nourishment is conveyed upwards in the tree, as I suppose.

But, as these smaller vessels, which are plainly to be seen by the microscope, cannot, by reason of their minuteness be well expressed in a drawing, unless still more enlarged, I used a microscope of greater magnifying power, and caused a small portion of the wood which in *fig. 6*, is situated between the two larger vessels, K and L, to be drawn somewhat larger than it appeared through the microscope before which it was placed, and this is shewn in *fig. 7. ABCD*.

This piece of wood was so cut, that all the horizontal vessels were exactly divided, and I could plainly perceive them, whether I viewed the object upwards or downwards; and I further saw, that where the horizontal vessels lay, there the larger tubes of the wood were situated, as appears in this figure at AB, and DC, which is where the horizontal vessels were situated.

In *fig. 6*, are also shewn, the horizontal vessels which take their course among the perpendicular vessels or tubes of the wood, but, as all the ascending vessels or tubes are cut transversely, so that their cavities become conspicuous, on the contrary, the horizontal vessels, by this manner of cutting, preserve their shape as near as may be. In this figure there appear more of these last vessels about the parts marked A and B, than about G, or between G and F; the reason of which is, that in splitting the wood, the knife did not pass in so straight a direction along those vessels as I wished: for the same reason these horizontal vessels appear in greater numbers at E, or between E and F, than about C.

In these horizontal vessels may be seen a red and yellowish substance, similar to the oily matter in the Nutmeg, and the young plant it contains, so that the horizontal vessels are of a reddish colour.

Farther, I determined to cut these horizontal vessels, each of which can be distinctly seen, and which generally lie three, or at the most, four together in rows, in an oblique manner, so as to exhibit their cavities to view. A small particle of the wood represented at *fig. 4.*

ABCD F, split lengthwise, at the part marked DF, I placed before a microscope, and this very thin particle, so split off, is shewn at *fig. 8*, PQRS, in which appear eight distinct places, where the horizontal vessels are cut in this oblique manner, as may be seen by the cavities in many of them, a part of which is shewn at Q.

The perpendicular ascending vessels, *fig. 8*, PS, or QR, are those small vessels, which in *fig. 6*, between K and L are shewn cut obliquely.

Moreover, I split this branch of wood in the middle, as the line AEC in *fig. 4* denotes, and from the piece so split, I cut a small particle, dividing the horizontal vessels longitudinally. This particle of wood is represented at *fig. 9*, TVWXYZAB, where TV, and YZ, are the ascending vessels, and the horizontal vessels which cross them, are shewn at WX and AB: and in, and among these horizontal vessels we saw various minute globules, which the limner, as nearly as he was able, imitated in the drawing.

In my observations on this wood, I saw four several kinds of woody tubes, besides other smaller ones, which, by reason of their minuteness, as I judged, could not be distinctly seen; but those which could be distinguished I caused to be drawn.

Fig. 10, CD, represents a tube of the wood partly composed of annular parts, like a wire wound round a pin; and, next this a tube formed in a different manner, seeming to consist of a pellucid membrane, covered with many small dots or specks, which in several places were contiguous to each other; this tube is represented in *fig. 10*, at EE.

Fig. 11, GH, represents a third tube of the wood, covered with smaller specks or dots, but, what is more remarkable, it contains in this small space five joints, very much like those of which straw is composed: two of these joints are represented at G and H.

I endeavoured also, if possible, to discover the formation of the larger tubes, shewn in *fig. 6*, at I, I, K, L, and while I was thus

employed, it appeared to me, that the transparent membrane constituting the tube, was composed of vessels taking their course round about the tube.

To make proof of this, I tore some of these tubes of the wood asunder longitudinally, when I perceived, that where torn, they were very much indented or jagged, whence I concluded, that however transparent they might appear to me, they were yet composed of a great number of vessels lying in a circular direction.

Fig. 12, I K, represents a part of one of those larger tubes so torn and jagged, which is very closely united to the adjoining small vessel at *LM* in the same figure, and from which, as I think, this larger tube received nourishment in its growth, and the rather because, though the membrane or coat of this tube appeared transparent, yet it plainly appeared, that the membrane was composed of minute vessels, which appeared to derive their origin from that small vessel.

I then proceeded to examine these larger tubes of the wood, with all the accuracy I was able, and I was well assured, that I saw the membrane composing them to be made of vessels like streaks crossing each other at right angles; a particle of this membrane is shewn in *fig. 12*, at *LNOI*, where the vessels or streaks from *I* to *N* and from *L* to *O* mutually cross each other, by which means this thin substance is strengthened; and who can tell how many, and what various parts such a tube of the wood may contain?

I think I have formerly said, respecting the veins in the leaves of trees, that they are of a spiral twisted form, like that represented in *fig. 10* at *CD*; and also, that the string by which many nuts (as the filberd, almond, &c.) have nourishment conveyed to them through the hard shells, consists of many vessels of the like kind, and upon recollecting this I determined, as far as I was able, to dissect the young plant I had taken out of the Nutmeg, to see whether the vessels represented in *fig. 10*, at *CD* and which are in great numbers in the wood, could also be found in the young plant.

For this purpose, I first examined the leaf of the young plant, in that part where it was so thick as to be opaque, and immediately I saw in it three distinct vessels of the like spiral or twisted form, as I have before mentioned to have seen in the root. This enquiry I prosecuted as far as the extremity of the leaf, where I saw a small vessel of the like kind, and so distinctly, that I could count every single fold or spiral turning in it.

Since it now appears plain to us, that provident Nature forms all the vessels of this tree in so perfect a manner, that the small ones in a young plant in the seed, are as plainly to be seen as those in the wood at full growth, which we may justly conclude is the case in all seeds, however minute ; we are not to wonder that the smallest of any animal which we view by the microscope, is as completely provided with all its parts as when it is grown larger. In a word, the farther we endeavour to dive into the hidden works of Nature, the more we ought to be convinced, that we never can arrive at her farthest recesses, though many persons, when making use of a good microscope, weakly suppose, that nothing is out of the reach of their observation.



(938)

On damaged Mace, commonly called white Mace; the cause from whence this defect arises, shewn to be an insect which feeds on the internal parts of the Mace, with a particular description of that insect; and some farther account of the Nutmeg.

UPON hearing formerly, mention made of that sort of Mace which is denominated white Mace, I merely thought, that it was not so good either in flavour or virtue as the reddish-coloured Mace, and the rather, as I long ago heard that a certain physician had the art to give the white Mace the same colour as the best; but having been since informed that this white Mace had so little virtue, that it was sorted from the rest and burnt, and hearing that its inferiority was supposed to proceed from some defect or want of nourishment in the growth of the plant, I had a great desire to examine the nature of this white Mace.

On conversing upon this subject with one of the Directors of our East India Company, he informed me of the time when the officers at the Company's warehouse, were employed to sort out the white Mace, and gave me permission to go to the warehouse and satisfy my curiosity in this respect. I accordingly attended at the warehouse, and perceived, not without surprize, that the white Mace was composed of nothing but thin membranes or skins, and I also observed a kind of webs, which I concluded had been spun by some insect, which webs were fixed to some of the Mace, not only the sound, but also the damaged. I brought home with me eight or ten of these webs, and found them to be covered in part

with certain oblong black particles, which I concluded to be the excrements of the maggots, by which those webs had been spun: in several of these webs, I also saw certain particles which seemed to be the fragments of aurelias, from which some species of flying insect had proceeded, and, as in one of these webs I perceived several minute feathers, very much like those found on the wings of moths, I further concluded, that the flying insects which proceeded from these webs must bear some resemblance to the moths in this country.

In order to satisfy myself further, I went the next day to the Company's warehouse, and spent a whole hour with some of the officers in search of these webs, and at the same time, the officers gave me a leaf or piece of Mace very much shrivelled, in which was the appearance of a web, and on opening the leaf, I found in it a white flying insect, (which was not only dead, but had lost some of its legs,) in shape and size not unlike those white moths that are found in granaries, and from whose eggs proceeds the maggot called the wolf,* though I judged this insect to be of a different species. Upon my return home, I examined all the webs I had found, and in several of them, discovered the skins or cases of aurelias, from which flying insects had proceeded, and in two of them, the insects themselves; I also found one perfect crysalis, and in it the insect dead; and upon attentively examining this crysalis, I plainly perceived that it was exactly of the same shape and nature with all the other skins of aurelias which I had found. I caused a drawing to be made of this aurelia or crysalis of the same size it appeared to the naked eye; this is shewn at figure 13, AB, in which the resemblance is taken as accurately as the limner could imitate it in his drawing.

Fig. 14. CD represents the flying insect which proceeded from one of these aurelias; the wings of which, would I believe, have appeared longer than here represented, had not the animal while

* The description of this insect is to be seen at page 25.

struggling to get out from amongst the Mace where it was enclosed, broken off part of them, in which struggle also, I fancy it had been killed.

After this, I applied myself to examine the white Mace, as it is called, a parcel of which I had brought home with me; and I immediately perceived that all the matter or substance which had been enclosed between the membranes composing the outward surface of the Mace, was consumed or eaten away. This substance, which for the most part, consists of oily globules, in which the whole virtue of the Mace consists, being so stripped from those membranes (of which membranes, the leaves of all plants, however small they be, are composed, and whereby the internal moisture of the leaf is kept from evaporation) nothing remains but the thin membranes themselves, consisting of wonderfully minute vessels, lying lengthwise in the leaf, which altogether exhibit a white appearance: hence these leaves are called white leaves, or white flowers of Mace, whereas, in fact they are nothing but the very thin membranes of those leaves.

I found, on the inside of these membranes, various oblong particles pointed at the ends, and some of them transparent; these I concluded to be the excrements of the maggots I have mentioned, and to have been voided by them at different periods of their growth, because, though of different sizes, these particles were all of the same shape. Farther, I observed some of the broader leaves of Mace to be so eaten away, that only one of the membranes remained, and having in vain sought among them for any animalcule, I threw them all away.

After this, I procured a fresh supply of the white leaves of Mace, not doubting that I should find some dead animals among them. At length, after a long search, I found a small white particle, not larger than a grain of sand, which, examining by the microscope, I found to be an animalcule, the hind part of whose body was transf-

parent and oblong, but the fore part was covered with some extraneous matter, which endeavouring to wipe away, I broke it off from the hind part.

I was, however, hereby induced to make a further search, not doubting, that I should find some of these insects of a large size, but I could not discover any of them among the leaves whose membranes were entirely stripped of their contents; whence I concluded, that the maggots, when grown large, had either quitted the leaves or undergone a change in their form, whereupon I sat about examining those white leaves which lay next the others that were found, as also those leaves which were in great part, but not wholly, consumed; six or seven of which I had brought with me; and among these, I found a few animalcules of the same shape with the one I last mentioned; these were not only larger than the former, but their bodies were of a reddish colour, and I judged that this colour proceeded from their feeding on the oily matter, of which the Mace, for the greatest part consists, and that the former transparent animal had died before it had fed on that coloured substance.

At *fig. 15*, is shewn one of these maggots, of the same size as it appeared to the naked eye; this was one of the largest that I had met with in my search.

The discovery of these maggots very much excited my admiration, because I had never seen any thing like them in the Nutmeg, and the more, because these maggots feed and subsist on the oil in the Mace, of which oil the Nutmegs are also in part composed. But the reason why those animalcules, which seek their food in the Nutmeg are not found in the Mace, is, in my opinion this, that those which devour the Nutmeg avoid the oily matter it contains and only feed on those parts of the nut where there is little or none of that oil.

Having thus discovered the maggots (described in *fig. 15*,) which feed on that thin matter or substance found within the membranes of

the Mace, and which afterwards quit the Mace, leaving the membranes themselves unhurt, except in that part where they first gained admittance; I caused a drawing to be made of some of these Mace leaves, a part of which is of that sort called white Mace.

Fig. 16, A B K C D E, exhibits part of a leaf of Mace, and in this figure, between *E F G* and *H*, may be seen the stripes of the leaf, which are engraved with very light touches, so as to give the appearance of white; these are the parts called white Mace, and from them the oily substance is all consumed, leaving only the bare membranes. Now, if this whiteness had been caused by the want of nourishment in the plant, then the extremities of the leaves at *C* or *D*, would have been white also, whereas, on the contrary, they were of the proper colour, and of a good flavour, by reason that the maggots had not eaten away the oil from within the membranes farther than where the leaves appeared white.

Lower down, in the figure, between *G* and *H*, may be seen a small hole made in the membrane of the leaf, which I conclude, was bitten by the maggot, to open for itself a passage into the leaf, and the rather, because the thin membranes in this part of the leaf were entirely unhurt, nor did there appear any perforation in them, except in the before mentioned place towards *A B*. And, if we consider the narrowness of the cavity in these white leaves, where the oil is eaten away, we may conclude, that it must have been an exceeding minute creature which could turn itself about in so small a space, and then procure its subsistence; and, between the membranes in this part of the leaf, I found nothing, except the excrements of the maggot.

When I was endeavouring, some time since, to discover the young plant in the Nutmeg, I also tried to find out, in what manner the nut, while inclosed in its shell, received nourishment from the tree; and for that purpose, I took a Nutmeg which was preserved in sugar,

and dissected it, but, as the syrup had penetrated into the inside of the nut and was there candied, my search was at that time fruitless; however, during my present inquiry, the sorters of spices presented me with six or eight Nutmegs, which they had found among the Mace, which, with their original husks, and the Mace inclosing them, altogether somewhat bigger than large hazel nuts; and also two of the same, somewhat larger.

Upon examining these nuts attentively, I perceived, that the skin which covers the hard bark or shell of the Nutmeg, was perforated in some places among the Mace, though the Mace leaves themselves were unhurt; hence I judged, that this perforation was the work of those maggots, or animalcules which I have in another place mentioned, as feeding on those parts of the Nutmeg wherein there is none of the oily matter composing the Mace, on which oil they cannot subsist.

I viewed the Mace which inclosed these Nutmegs by the microscope, and found it to be covered with many dried bodies of mites, but in all my search, I could not discover any living mite, whence I concluded, that the packages inclosing these Nutmegs, had been stowed in a part of the ship near the bread-room, and, upon enquiry, I found that this had actually been the case; so that I doubt not, these mites, which multiply in vast numbers among the bread, had been killed, when the packages of Nutmegs and Mace were stowed there: and this confirms what I have, in another place mentioned, that the vapour of Nutmegs is mortal to those creatures.

Farther, upon examining these Nutmegs, and the leaves of Mace inclosing them, I observed in several of them, that, at the part where they receive their nourishment from the tree, they were perforated with a small round hole, penetrating into the nut itself, the Mace for the most part appearing untouched; and this was done where the bark of the nut was the softest: in one of these holes I found a

dead flying insect, of the same species with those, many of which I have mentioned to have found in the Nutmeg. Upon breaking open one of these nuts, I saw, that all the internal whitish substance of it, where there had been little of the oil, was eaten away, and nothing left in the cavity except the excrements of the maggot, and the web it had spun while in that place; but, as I did not find any skin or remnant of an aurelia, I judged that the maggot, not finding a sufficient quantity of sustenance in this nut, had quitted it before it arrived at its full growth. On this occasion, I could not but admire the instinct which teaches these insects to perforate the hard shell of the Nutmegs, and for that purpose, to find out that part in it which is softer than the rest; for this I found to be the case not merely in one or two instances, but in as many as ten Nutmegs, I observed the same.

Fig. 17, L M N, represents the Nutmeg inclosed in its shell, and covered with the leaves of Mace, but which coverings are, in India stripped off while fresh and green. All these receive their growth and increase through the part between L and M, which is the place where the nut adjoins to the tree; and I at first thought, that the Nutmeg was nourished from its shell or bark, as I had observed was the case with the walnut; but upon a more careful investigation, and after cutting open the shell with a fine saw, I found, that I had been mistaken herein, for I could not discover any thing at the part marked L M, which had the appearance of having transmitted nourishment to the fruit. I soon, however, perceived two places adjoining to each other, one, as I concluded, for the nourishment of the bark, and the other of the nut itself; and, on further searching, I saw, that the vessels destined for this purpose, did not immediately enter the nut at that point, as I had observed in filberts, almonds, and other seeds, but that the vessels in this nut take a course from M in *fig. 17* to the point of the nut at N, and there pass through the

shell, and by this means, the nut receives its nourishment; for it is not united to its shell in any other place.

To exhibit this to the eye, I caused a drawing to be made of the bark or shell containing the Nutmeg, after the leaves of Mace had been stripped off, and having also first loosened from it the string through the vessels in which nourishment is conveyed, leaving only the string affixed to the part where it enters through the bark, to shew more plainly the place where the nut receives its nourishment.

Fig. 18, O P Q, represents the bark or shell wherein the Nutmeg is inclosed; Q R, is the string, consisting of multitudes of vessels which convey nourishment to the nut; O and Q exhibit the furrow or crease wherein the string lay before it was pulled out. This string I cut into very thin slices, some of which I placed before the microscope, that I might the better discern the great number of vessels in them, of which I caused a drawing to be made, as nearly as they could be distinguished and represented. This is shewn in *fig. 19*, A B C D E, being one of the slices I have mentioned, cut obliquely, and magnified.

Now, if we contemplate the incredible number of vessels in so small a string, (for that which in *fig. 18* is shewn at Q R, is, in reality twice the size of the real string, because I did not strip it of the skin which covered it, lest I should injure the vessels it contained) besides those which the sight cannot reach, we must conclude, and be assured, that there is not a vessel in a full grown Nutmeg tree, for whatever use it may be destined, but there is a similar one in this string; otherwise it could not communicate to the young plant in the Nutmeg, all the vessels requisite for the formation of the future tree and fruit.

In a word, the inconceivable perfections which are contained in these strings of plants, and consequently in every seed, are to us incomprehensible, and, still more, inscrutable.

Moreover, I have given a drawing of the bark or shell of the Nutmeg, when broken in two, having first stuck a pin into the place through which the string, which I have been describing passes, in order more plainly to shew the nature of it. This is represented at *fig. 20*, S T V, in which figure, W X is the pin, marking the place through which the string passed, and at Y is a kind of protuberance on the inside of the shell; in the nut itself is a cavity corresponding with it, and above this cavity, is the place where the string is united to the nut; but the strings are almost always broken from the Nutmegs before they arrive in Europe, because the nuts in drying, or by the evaporation of their moisture, become smaller, whereas the hard shell dries and shrinks little or nothing, so that the nut getting loose within, does, by its weight break off the string, and, when shaken in the shell may be heard to rattle.

At *fig. 21*, F G H, is a drawing of a piece of the shell at that end next the tree, and at K is the round hole I have mentioned, in one of which holes, I found a flying insect: in this figure also, that part of the string conveying the nourishment to the nut, and which here, is joined to the tree, is shewn at I K L: this shell being removed, I found that the animal had penetrated into the nut as I have before observed.

Fig. 22, M N O, represents the nut itself, in which the above mentioned small hole, is shewn between P and Q: at this place, the young plant is situated in the nut, and here also, as far as I have ever observed, the insects penetrate the nuts because it is the softest part of the fruit, and contains the least of the oil.

Since we now see, that these creatures, not only when maggots, but also when changed into flying insects, feed on those parts of the nut where the oil least abounds, we may readily conclude that, however minute, they are very pernicious to Nutmegs. In the state of flying insects, however, they are not, in my opinion, so hurtful on

account of their feeding on the Nutmeg, as by laying their eggs, the maggots proceeding from which, must be exceedingly pernicious, because they acquire their whole growth within the nut.

I am persuaded, that if the timber and wood in warehouses was painted with the common red paint used in this country, the spices might be preserved from many noxious insects, because the particles of that paint, though ground very fine, are of so hard a nature, that no small insect can penetrate them. And if the wood is observed to be perforated with many worm-holes, the painting should be repeated until all those holes are stopped up with it.

It may be said indeed, that Nutmegs and Mace are kept but a short time in the warehouses, and therefore not liable to be much injured; but in that short time, and while exposed to dry, they may be infected by these flying insects laying their eggs among them; and it is well known, that many of these creatures lay many eggs in a very little time. Indeed, if Nutmegs and Mace are kept in large heaps in the warehouses, I believe that only the surface of them might be exposed to injury, because the insects cannot penetrate far into the heaps to lay their eggs, and therefore the middle of these heaps may be uninjured.

But these matters are all conjecture, and, as it were, riddles to us at this distance, respecting which, those who are employed upon the spot, in collecting or drying the spices, could give much better information, if they were persons of intelligence and observation.

To return to the insects which I found among the Mace; I was doubtful how to pursue my enquiry respecting the generation of these creatures, and the rather, because those which I found, were not only dead, but their bodies very much dried, for, had they been living, I doubt not, that I should easily have discovered the manner in which their species is propagated.

At length, upon considering the shape and make of these mag-

gots, and, having seen by the microscope, that their bodies are formed with creases or rings, it occurred to me, that they were of that sort which do not bring forth young ones while in that state, but, like caterpillars, several kinds of maggots, and also fleas, change into aurelias, and these again into flying or creeping insects, and in that state couple and lay eggs.

Now, as I had found these maggots among the skins of the Mace, I concluded, that when their change approaches, it is in their nature to abandon the leaves : and, as in my former search I had found a crysalis, which I concluded had been changed from one of these maggots, inclosed in its shell or covering, I went a third time to the India Company's warehouse, and caused a considerable quantity of the white Mace to be put into a sieve and sifted, in expectation, that among the finer parts, which passed through the sieve, I should find several insects that had gone through their change.

By this means, I obtained two handfuls of small matter or dust, mixed with many minute particles of Mace, but I perceived, that the greater part consisted of the excrements of insects ; I also took a handful of dust, sifted from a parcel of Mace, before the officers had sorted the damaged from the sound : on my return, I carefully examined the whole, and found in it, at least one hundred dead animals, which I concluded had been produced from the before mentioned maggots, I also found two flying insects of the same sort with those which I had observed in the Nutmeg ; likewise the skins of two aurelias, and one of those creatures called a weevil, but which, as well as the rest, was dead. Such of these animals as had been produced by transmutation, were all of the like make, and almost of the same size as the full grown maggots, and I judged, that if they had not proceeded from those maggots, they would have been of different sizes.

Some of these maggots, I placed before different microscopes,

that I might cause a drawing to be made of such one of them as was the most perfect, because all that I found were not only dead, but so dried, that the least touch would break their bodies, or at least their feet.

I have already given at *fig.* 15, a drawing of one of these maggots, of the natural size; *Fig.* 23, EFGHIKLMNO, represents the same maggot as seen through the microscope: the body of this creature is formed with many joints or rings, also with six small feet, furnished with curious nails, the extremities of which nails are indented or notched, as shewn at G and N.

In the lower part of the body of this animal, as well on the belly as on the back, there appears an uncommon number of blood vessels, which, on each side of the body at H I and M L are the thickest, and largest, and seem to come from the inner part of the body: these blood vessels are divided into various exceedingly minute branches, several of which, proceeding from H to M, and from M to H there meet, and are again united, which not only appears in the branches about H and M, but also through the whole body, though the limner could not represent them all.

In the head of this creature, so many organs appeared, that they could not all be copied in the drawing.

At O and F are represented, two prettily shaped horns, made with joints, and covered with hairs: at E is the mouth, or rather two teeth, something like pincers, with which the maggot, as I judge bites into the leaves of the Nutmeg on which it feeds, and scrapes off the substance they contain, within the skin: P P are two other organs with which the head of this maggot is furnished.

I know very well, that these small animals are called bloodless, a name given to them by those, who, I suppose could not discover either the blood or the blood vessels, but this mistake I attribute only to their want of better information.

Now, as all caterpillars, maggots, and other small animals when changed into flying insects do still preserve the same sort of creases, rings, or divisions, which they originally had, so I perceived in the flying animal, produced from these maggots, the same kind of rings or divisions, but these did not become conspicuous till the two shells, or cases which covered the hind part of the body were removed: under these cases lie two exceeding small wings folded together, and by reason of their being longer than the body, doubled up: so that it seems probable to me, that these creatures are formed in the same manner as insects of the beetle kind, with regard to their wings, and the cases that cover them.

If we reflect on the nature of those flying animals, whose wings are thus folded up and covered with shields or cases, and who are destined to seek their food in hard substances, such as wood, nuts, and the like, or who are hatched in the earth, we shall see the necessity of their wings being formed in that manner, for if the wings were not longer than the hind parts of their bodies, they would be too small for flight, and if not defended by the cases or shields, they would be liable, when the animals are creeping into holes either in the earth or in the hard substances on which they feed, to be so broken or injured, as to be unfit for the purpose of bearing them through the air.

These animals, even after they are converted into flying insects, do, in my opinion, take food, contrary to what is observed in the moths or butterflies produced from silk-worms and caterpillars, for I observed, that some of these were of a bright and others of a dark red, the former of which, I suppose, had not been long changed, and therefore had not taken so much food as the latter.

I have often thought, that perhaps, these kinds of animals may feed upon wood, but, that when they get among Mace, which is of

a much softer nature, they may then multiply much faster than those which breed in wood, and especially in the harder sorts.

I placed one of these creatures, changed from the maggot into a flying insect, before the microscope, and having removed the shields or cases of its wings a little aside, in like manner as if the animal was living and about to take its flight, I beheld so wonderful a piece of workmanship, wrought with such curious art, that I determined to have a drawing made of it, though it was impossible to delineate all the wonders that were displayed in this minute animal.

Fig. 24, ABCDEFGHIKL, exhibits this flying animal, which appeared longer than the maggot from which it was produced, the reason of which I take to be, that the bodies of these maggots being very soft, they contract when their moisture evaporates, whereas when changed into flying animals their bodies are hard on the outside, and therefore cannot contract.

LM, and BN, are the two horns made with many joints and covered with hairs.

L, B, are the eyes composed of various optical organs, though but few in comparison of those which are found in the eyes of flies.

This creature has six feet, each furnished with two curiously made little claws; the legs are made with various joints at the extremities, and are covered with hairs, or rather with pointed particles like those on brambles: two of these legs with their claws, are shewn at CO and DP.

At DI and KI are pictured the two shields, or cases, with which the animal, when not in the act of flying, can cover the hind part of its body, so that I conclude, no particles of the wood, or of the Mace, nor any drops of water which may accidentally fall on its body, can injure the wings.

Upon attentively contemplating these shields or cases, I was

astonished at the wonderful and elaborate workmanship exhibited in this creature, which appears so minute to the naked eye, but does, I think, in perfection, far exceed the larger animals we daily behold.

If we advert to the hind part of the body, formed with joints indented in the same manner as in the maggot, from which, by transmutation it was produced, and observe the multitudes of veins, scattered over it, we must more and more be confounded at such great perfection in so minute a creature.

In like manner in the wings, we see many vessels and sinews, which sinews serve to expand and strengthen them; likewise many pointed particles or hairs, with which the membranes of the wings are covered: it is also worthy of observation, how the wings are folded and doubled up, both in length and breadth (which is shewn between G and H, as nearly as the limner could imitate it) in order that they may be entirely covered by the cases; besides which, this animal is provided with another exceedingly minute wing on each side. Let us also consider, with what inconceivably minute sinews or muscles these wings must be provided, in order that the animal, when it prepares for flight, may unfold them both in length and breadth; and how the joints and sinews must be contrived, so to strengthen the wings when unfolded, that by their swift vibrations, the animal may shape its course through the air.

In order, more clearly, to give an idea of the foldings in these wings, I took one of them from under its case, and placed it, together with the sinew or muscle which adhered to it, before a microscope, directing the limner to make a drawing of it, and also of the sinew, whereby the wing is unfolded and put in motion.

Fig. 25, QSVWXY, represents this wing according to its position when covered by the case or shell; V, is the broadest part of the wing, and this part lay either under or above the corresponding

wing. QR is the muscular part, by means of which, not only the wing is put in motion, but doubtless many lesser muscles are derived from this, by means of which, that part of the wing at WXY is extended in length, and the part at YQ expanded in breadth: at ST is the minute wing I mentioned above.

When we duly consider this most perfect workmanship of the Divine Artist, we must confess, that those things which we discover by our microscopes and industry, are but as the shadow of those which hitherto remain concealed from us, not only in such small animals as this now under consideration, but also in larger animals, and in plants.

It is to be hoped then, that the enquirers into Nature's works, by searching deeper and deeper into her hidden mysteries, will more and more place the discoveries of those truths before the eyes of all, so as to produce an aversion to the errors of former times, which all those who love the truth, ought diligently to aim at. For,

We cannot in any better manner, glorify the Lord and Creator of the Universe, than that, in all things, how small soever they appear to our naked eyes, but which yet have received the gift of life, and power of increase, we contemplate the display of his Omniscience and Perfections with the utmost admiration.

END OF THE FIRST VOLUME.



SIDNEY,—PRINTER, BLACK HORSE COURT, FLEET-STREET.

Fig 2

X

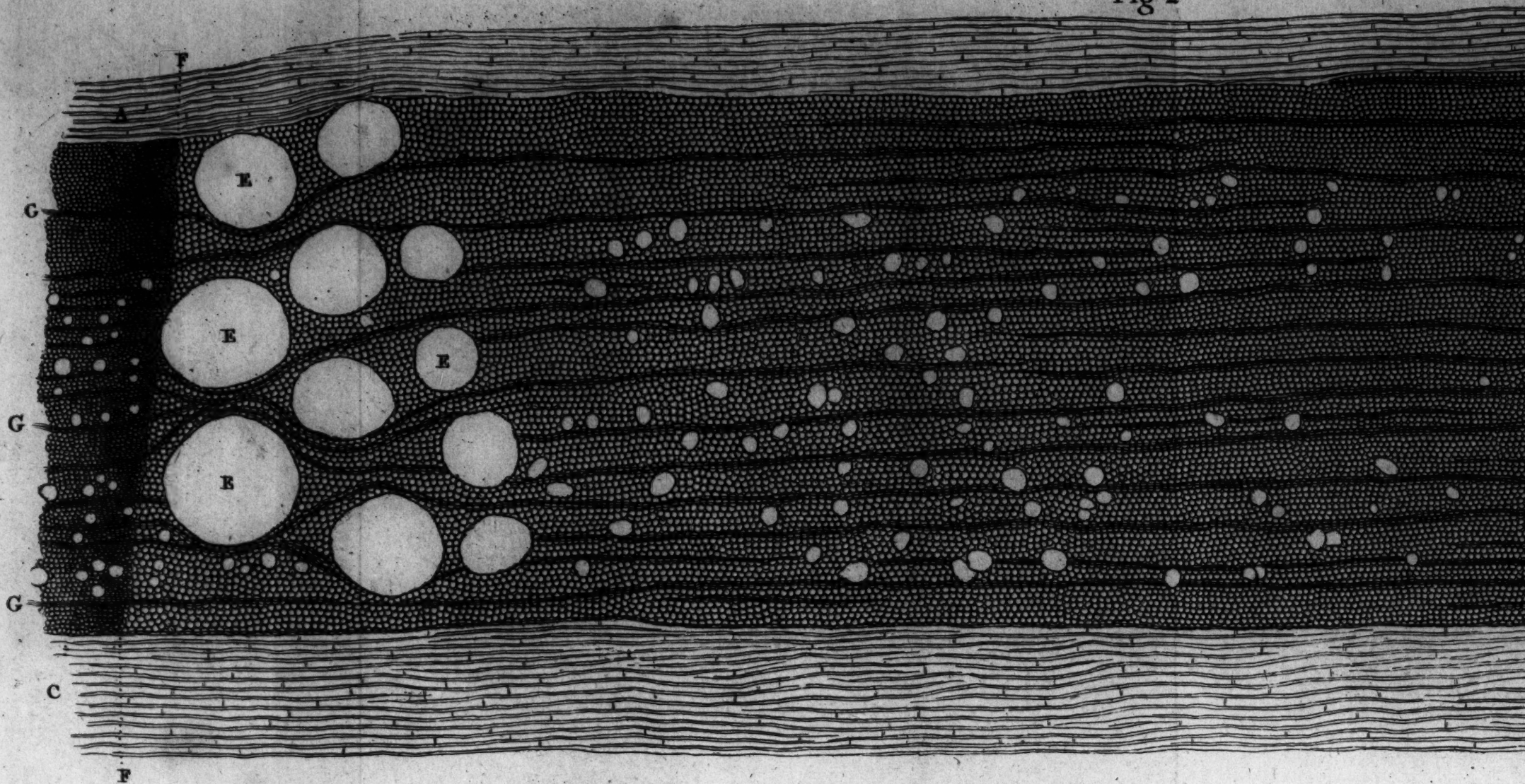


Fig. 5



Fig. 4

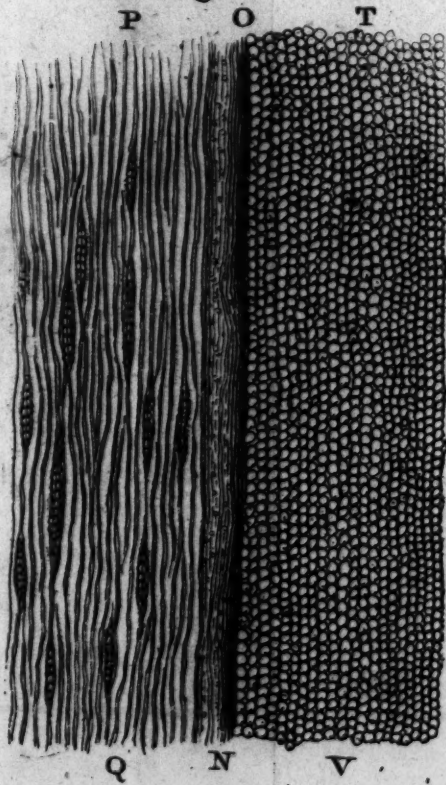


Fig. 3

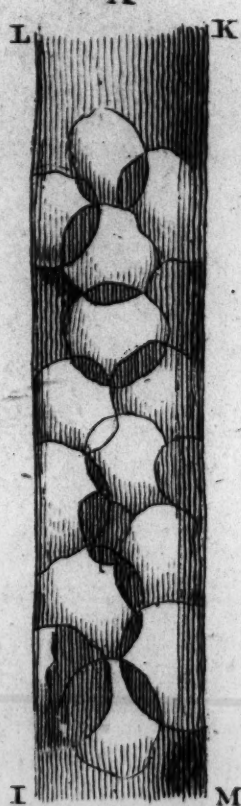


Fig. 8

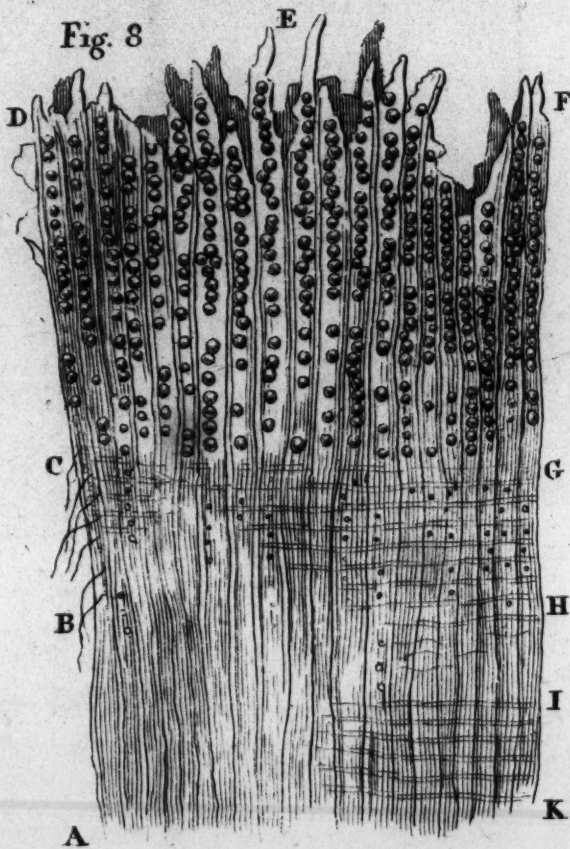


Fig. 1

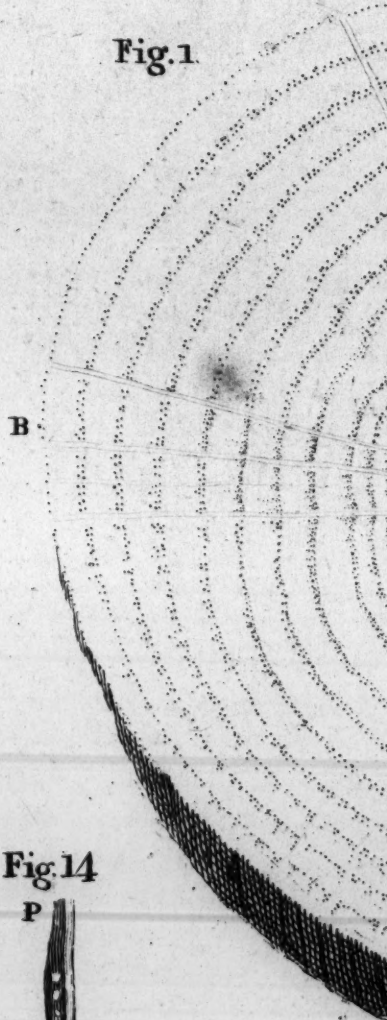


Fig. 9



Fig. 10



Fig. 11

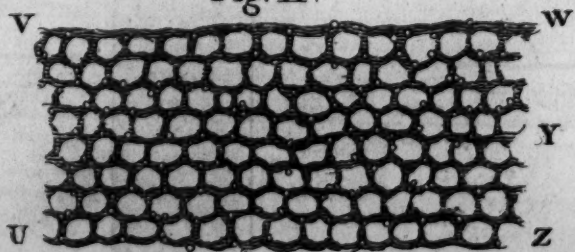


Fig. 12



Fig. 13



Fig. 14



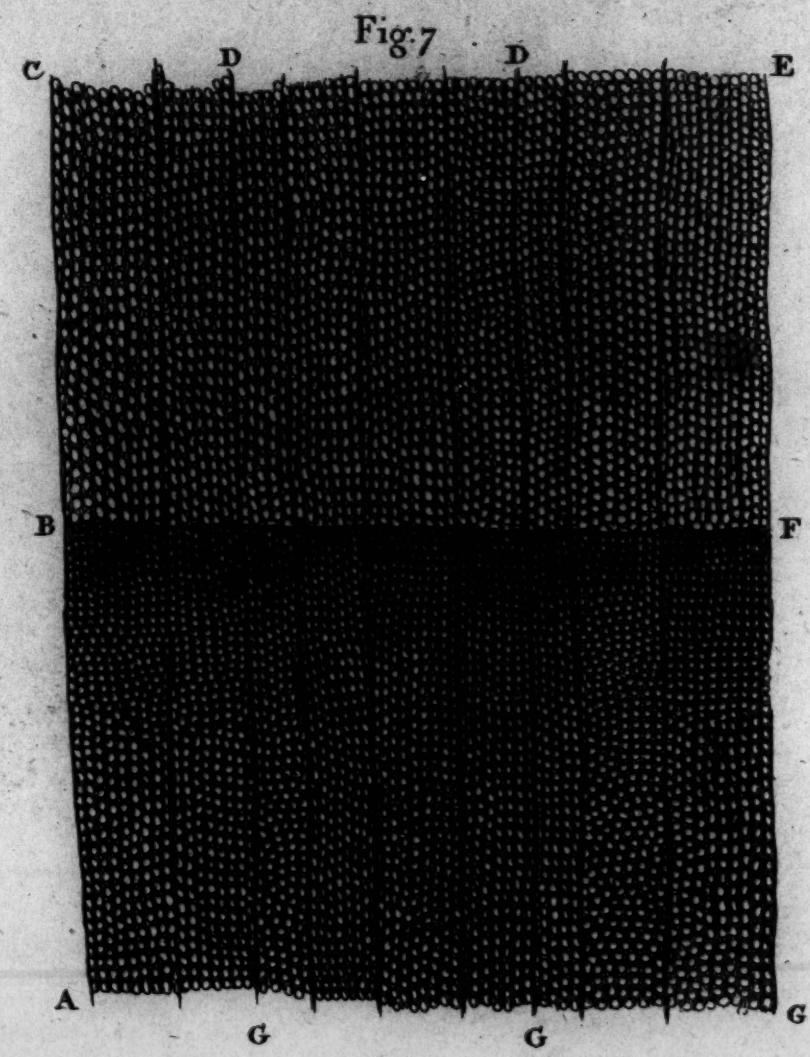
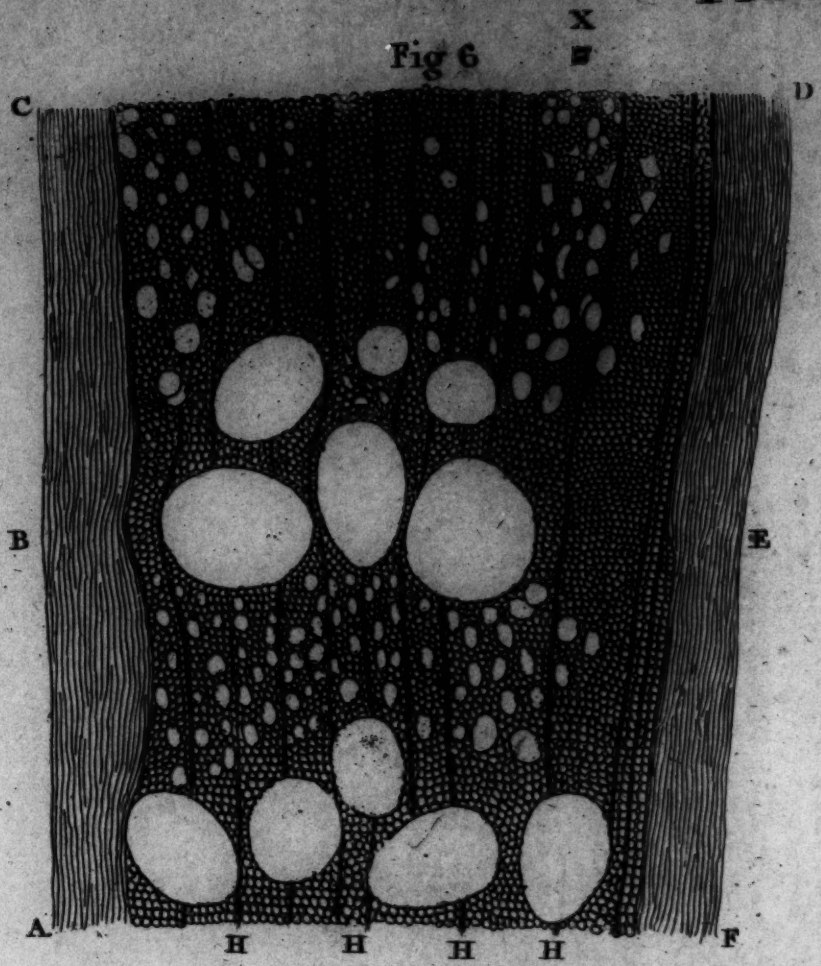
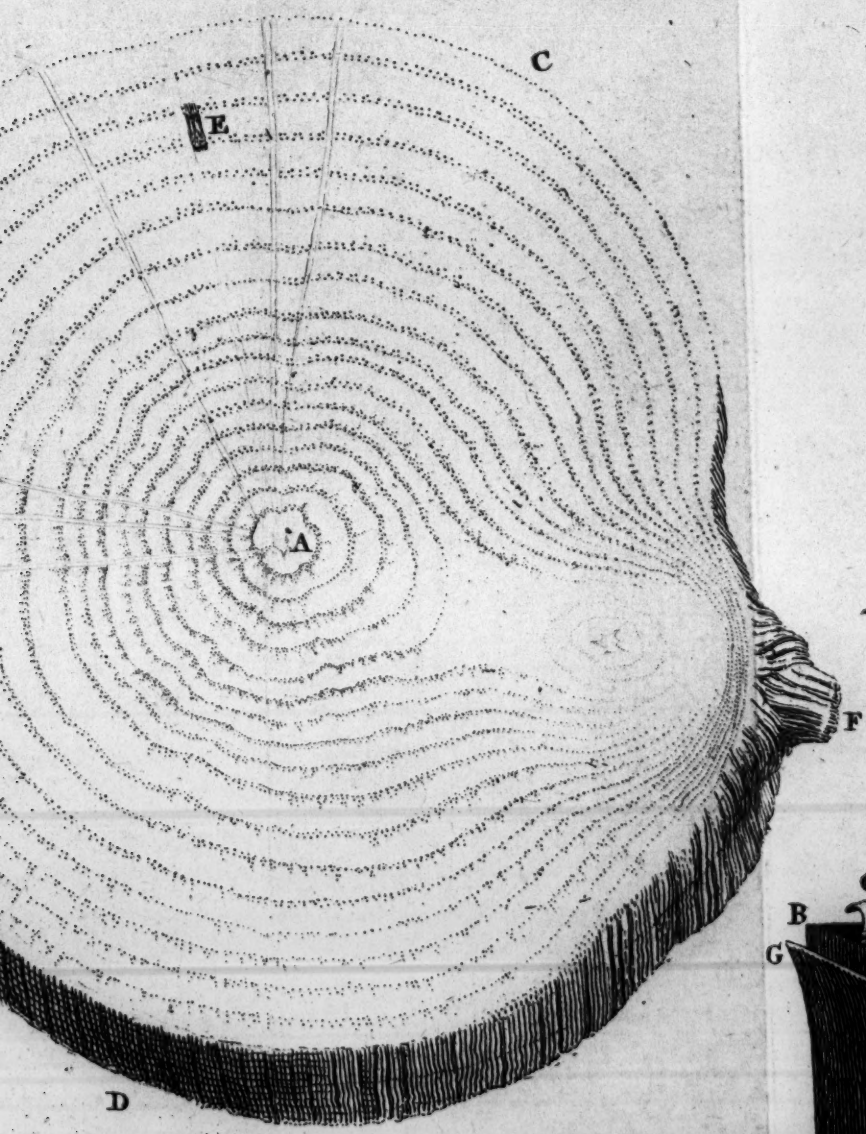
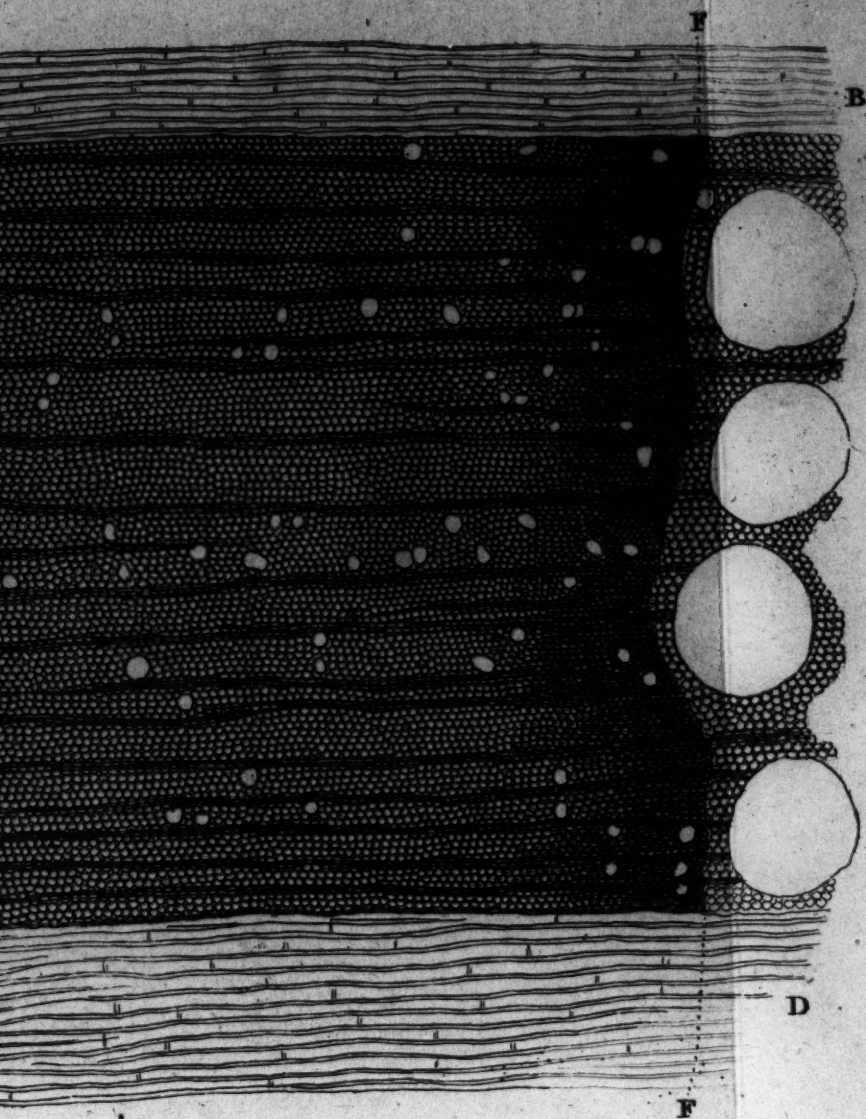


Fig 6

Fig 7

Fig 15

Fig.1



Fig.2

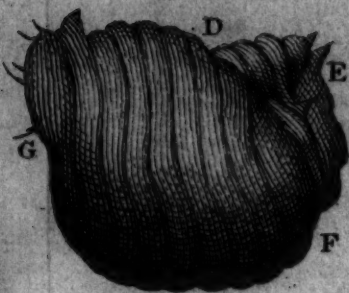


Fig.3

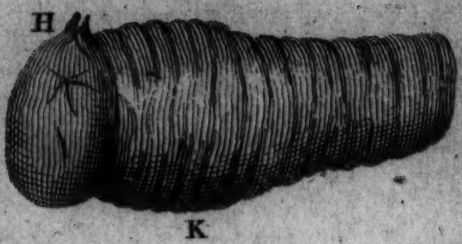


Fig.5

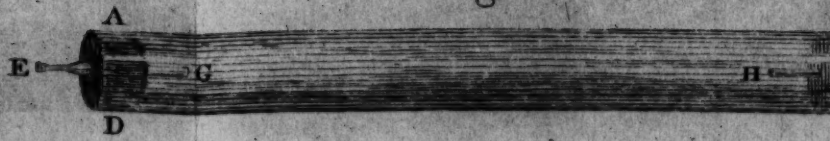


Fig.6



Fig.7



Fig.8

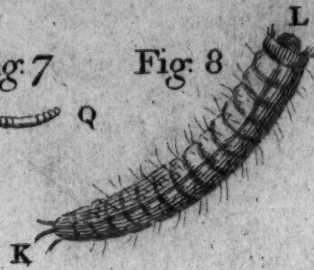


Fig.9



Fig.4

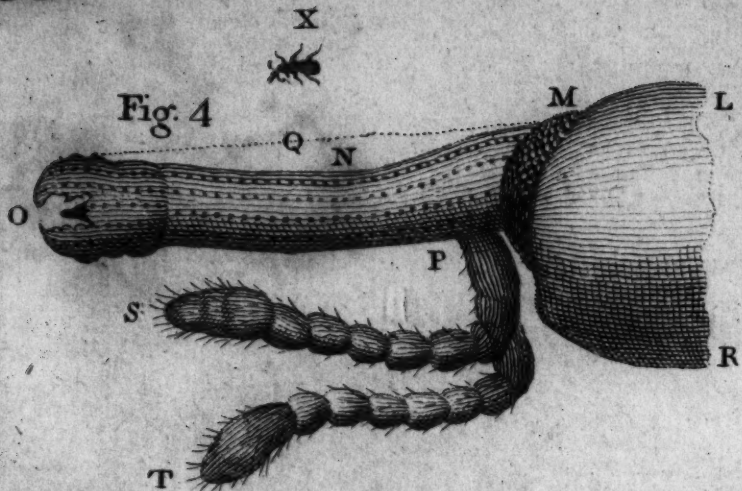


Fig.25



Fig.28

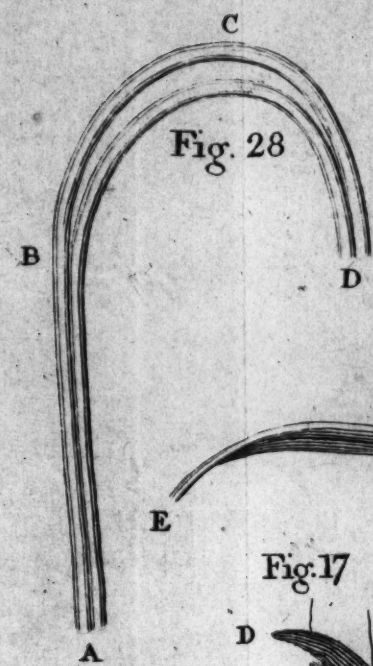


Fig.29

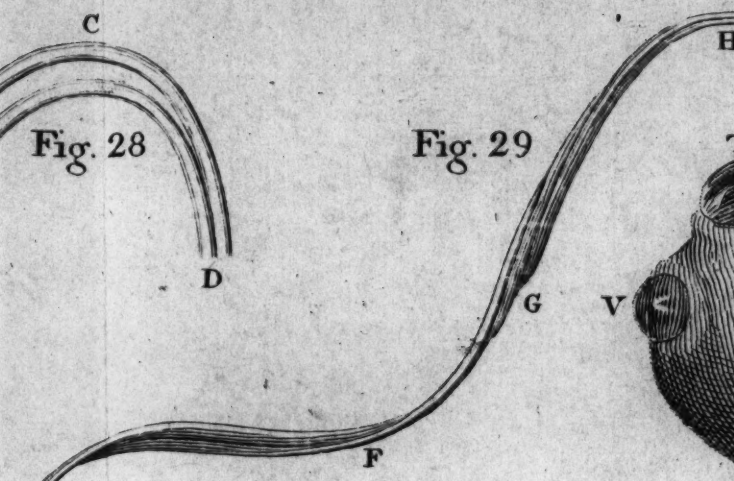


Fig.17



Fig.18



Fig.19

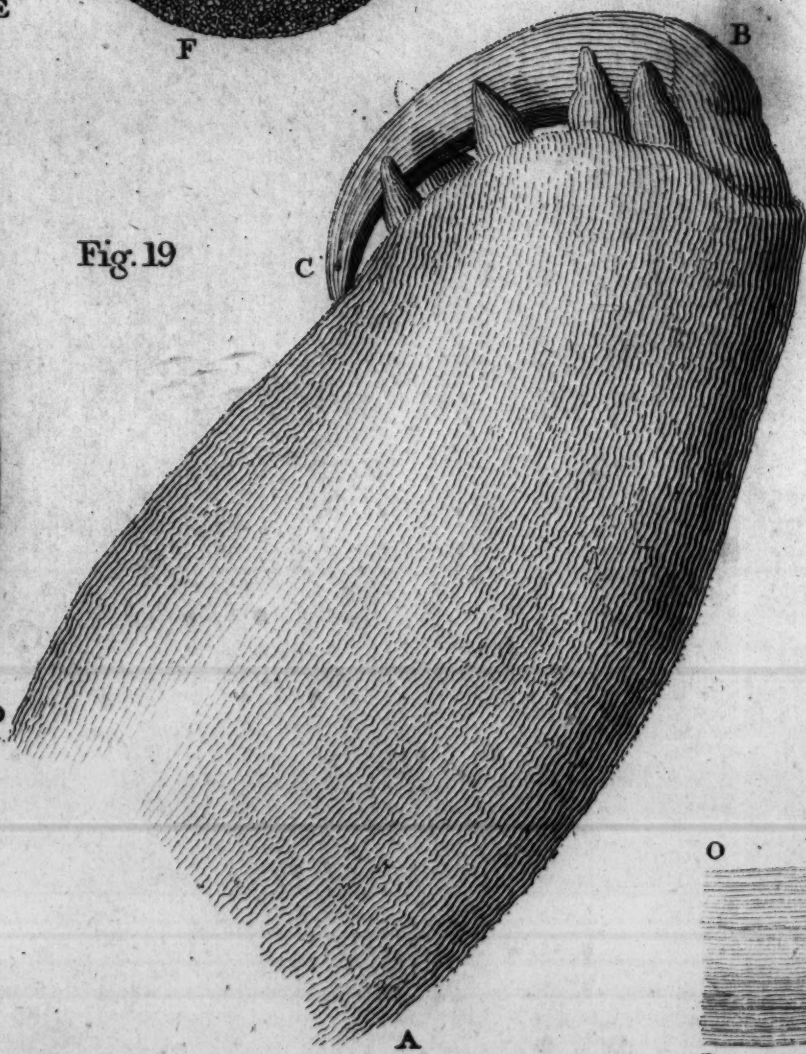
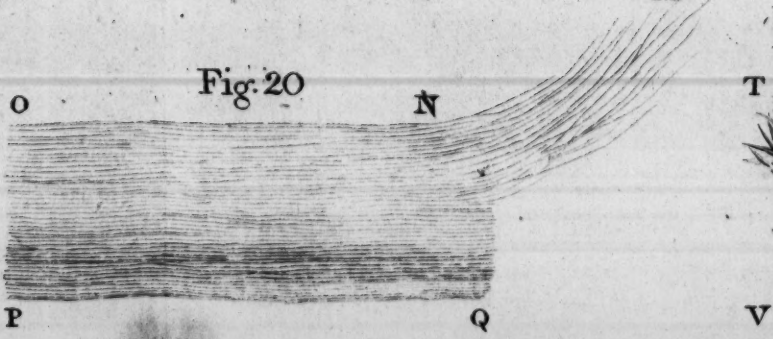


Fig.20



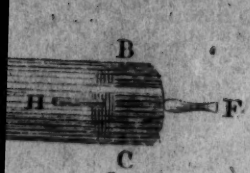


Fig. 10

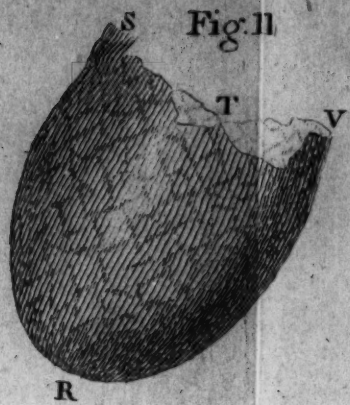


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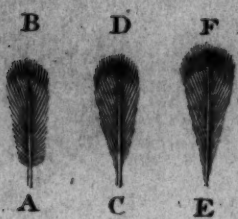


Fig. 14

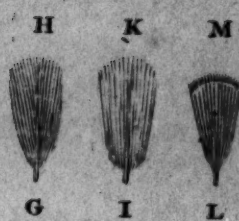


Fig. 15

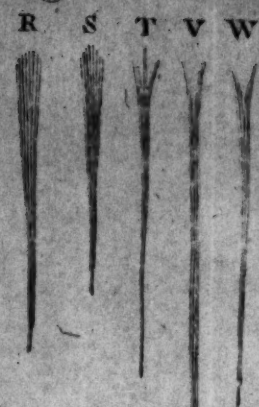


Fig. 16



Fig. 12

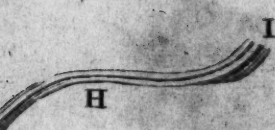


Fig. 27

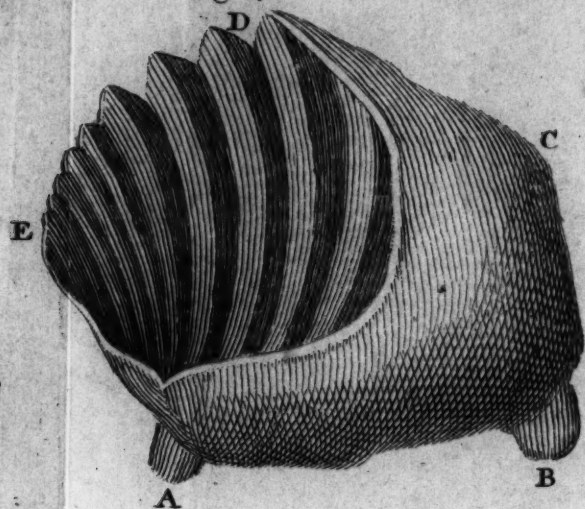


Fig. 30

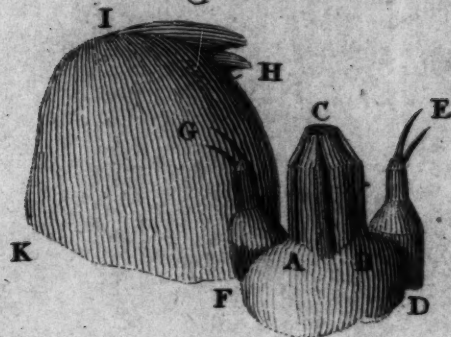


Fig. 26

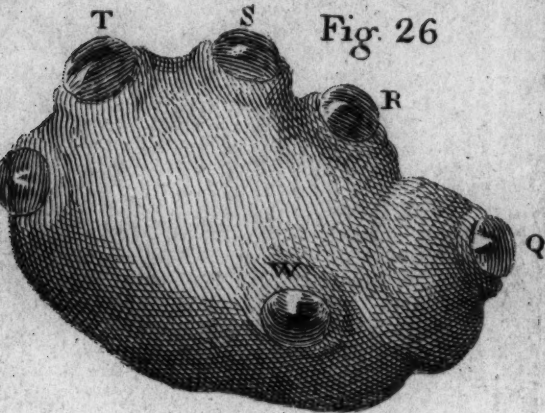


Fig. 31



Fig. 18



Fig. 32

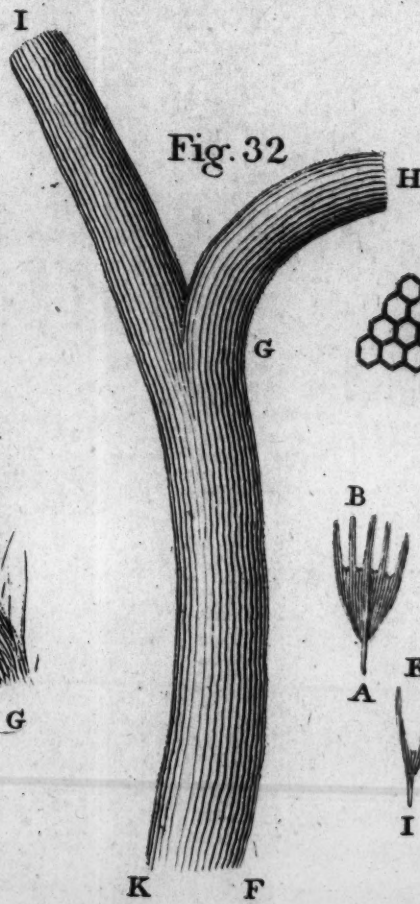


Fig. 33



Fig. 36

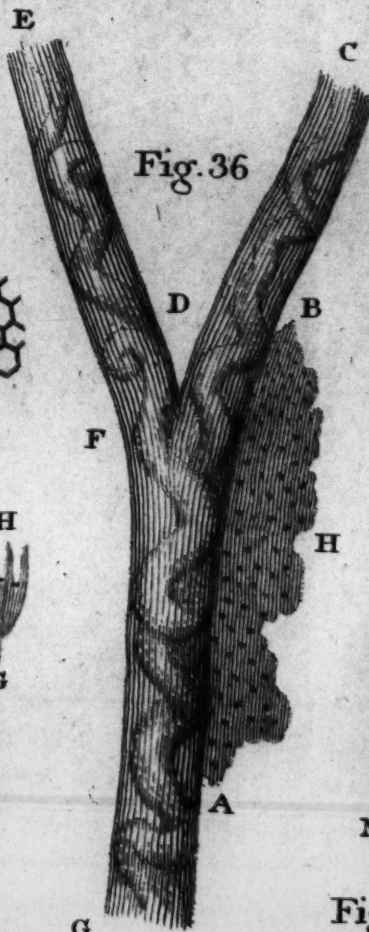


Fig. 37



Fig. 34



Fig. 38



Fig. 21

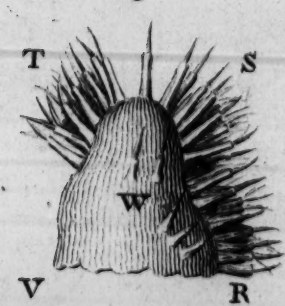


Fig. 22



Fig. 23



Fig. 24

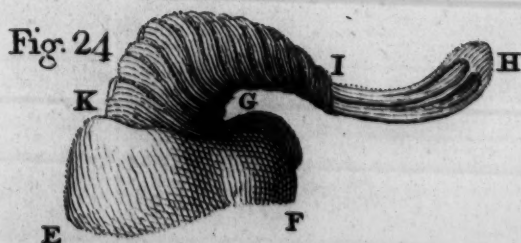


Fig. 35



Fig.1.



Fig.2.

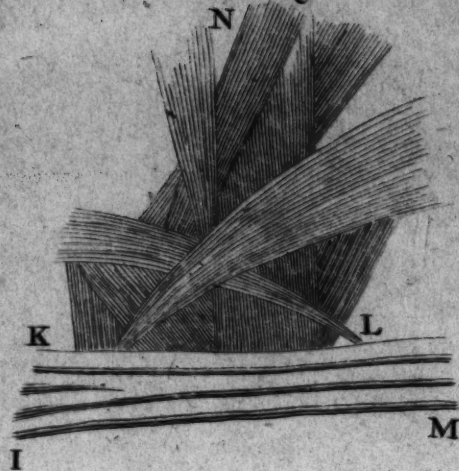


Fig.3.

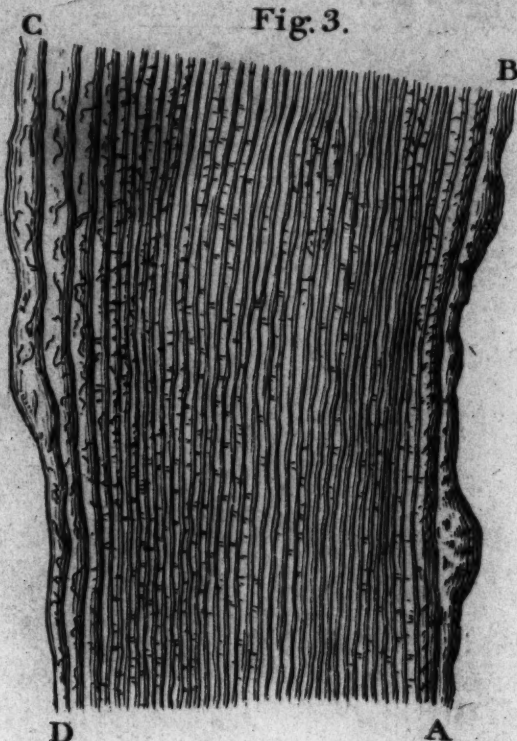


Fig.4.

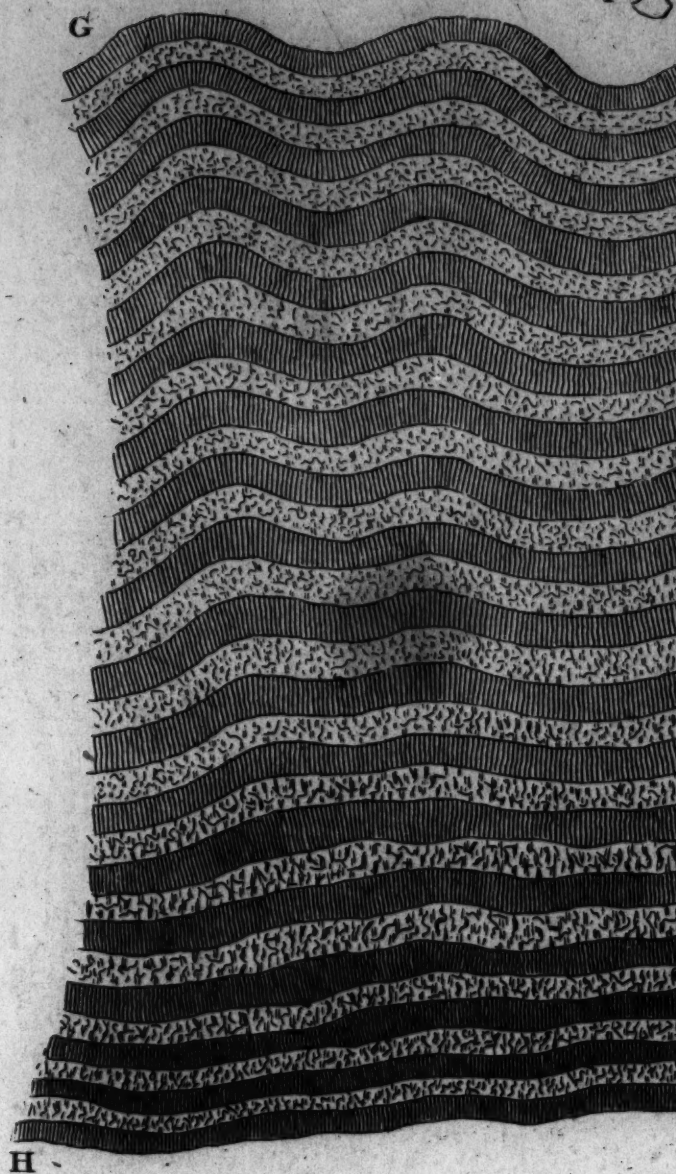


Fig.5.

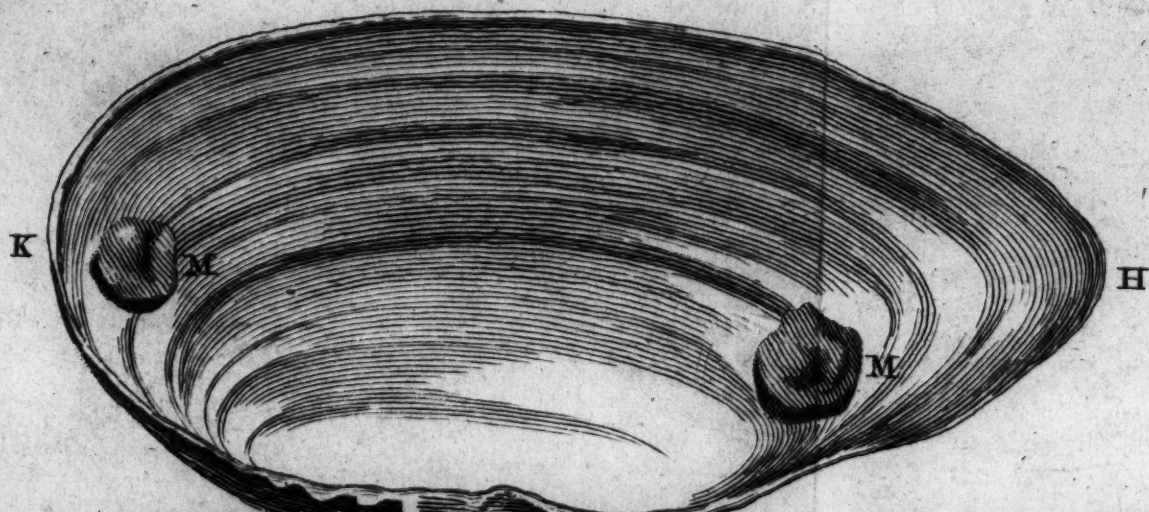
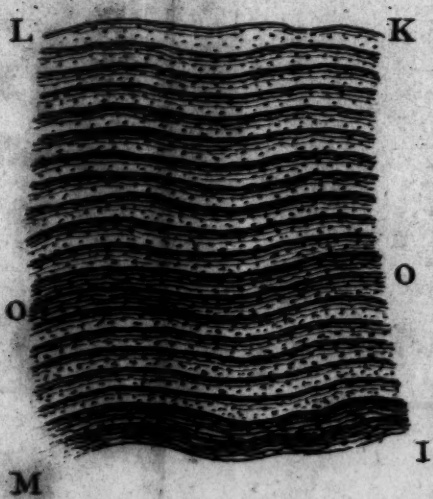


Fig.14.



Fig.15.

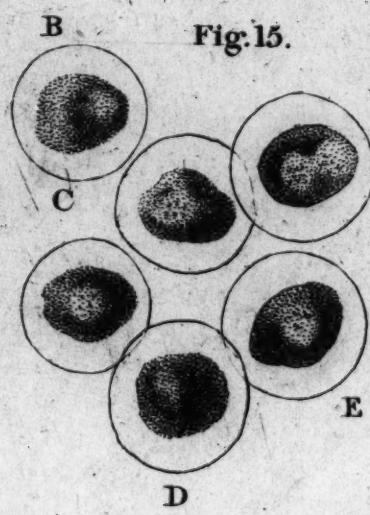


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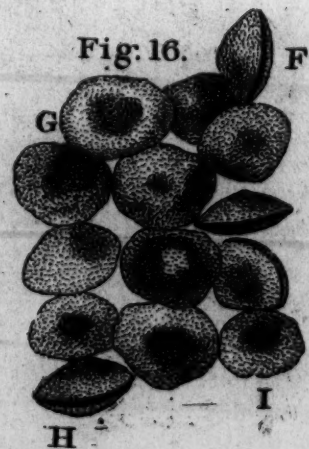


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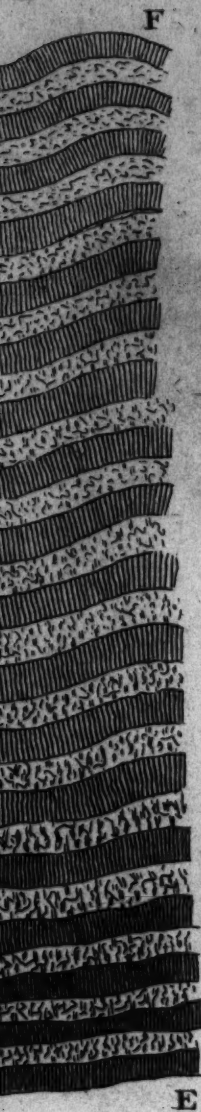


Fig. 7.



Fig. 9.



Fig. 8.

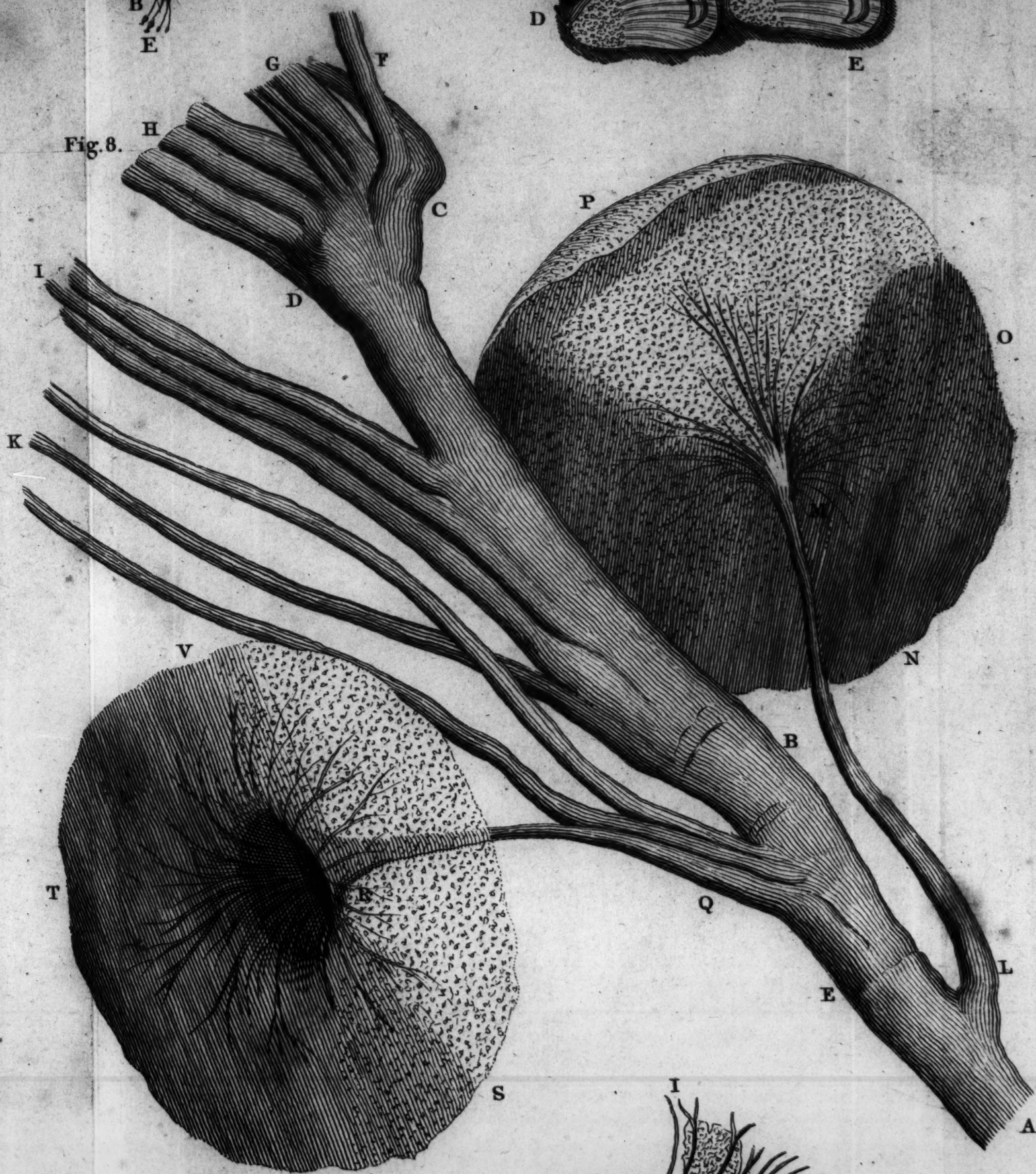


Fig. 10.



Fig. 13.



Fig. 12.



Fig. 11.



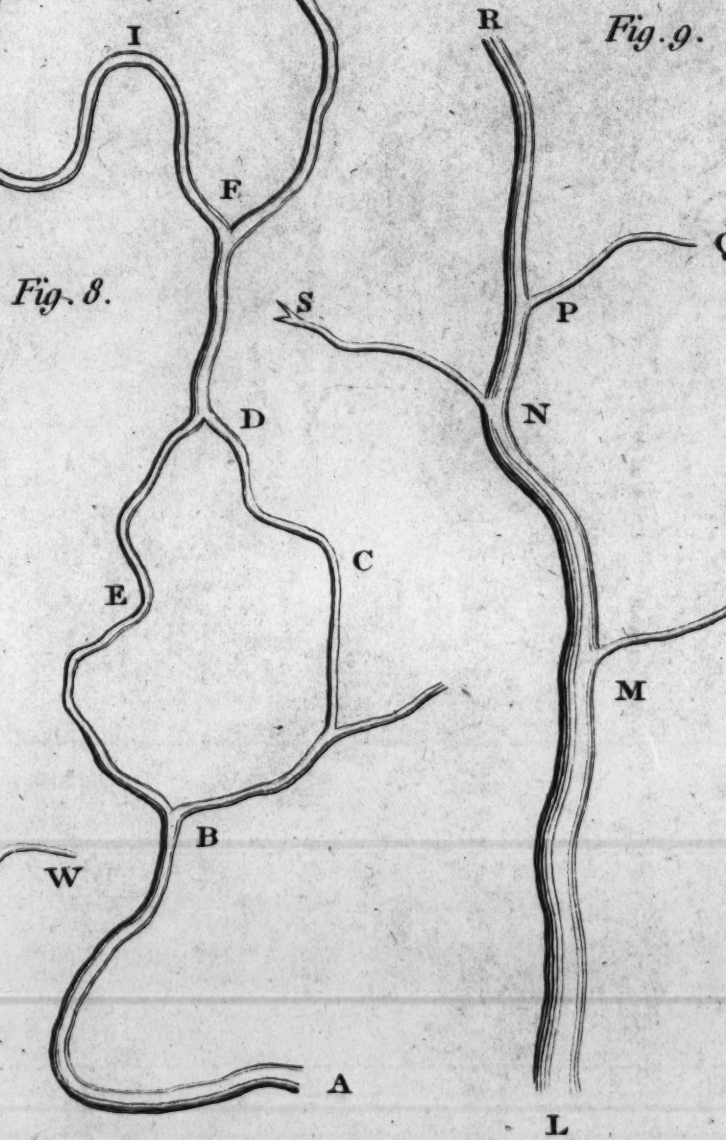
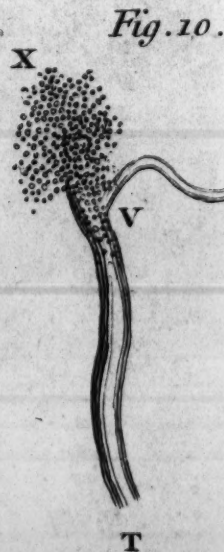
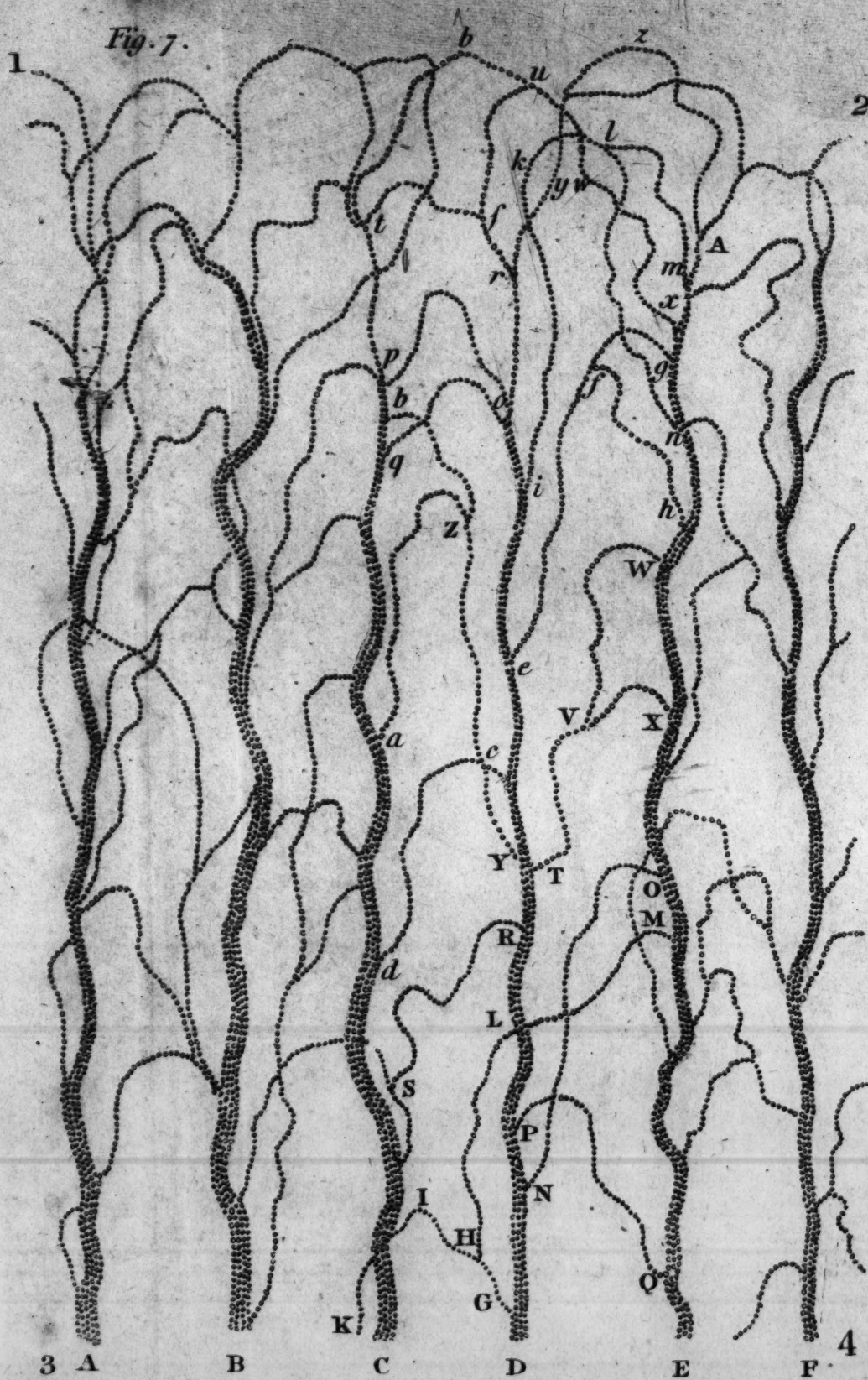
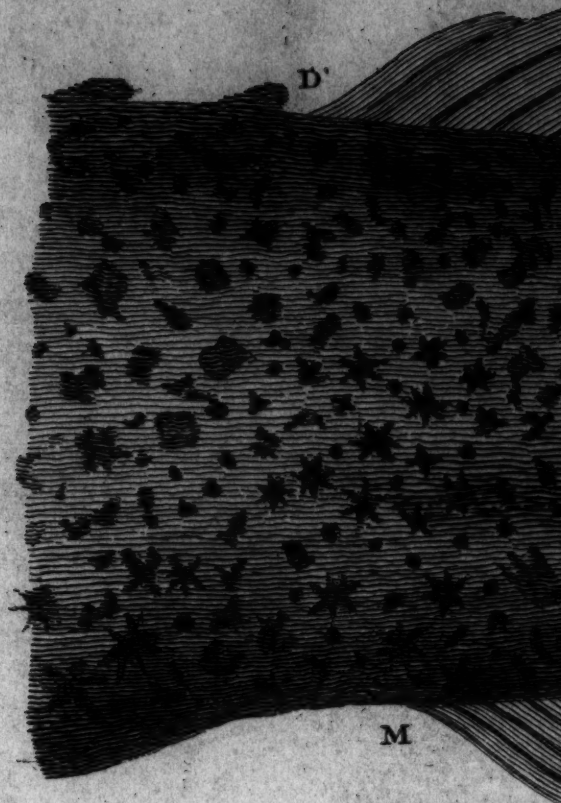
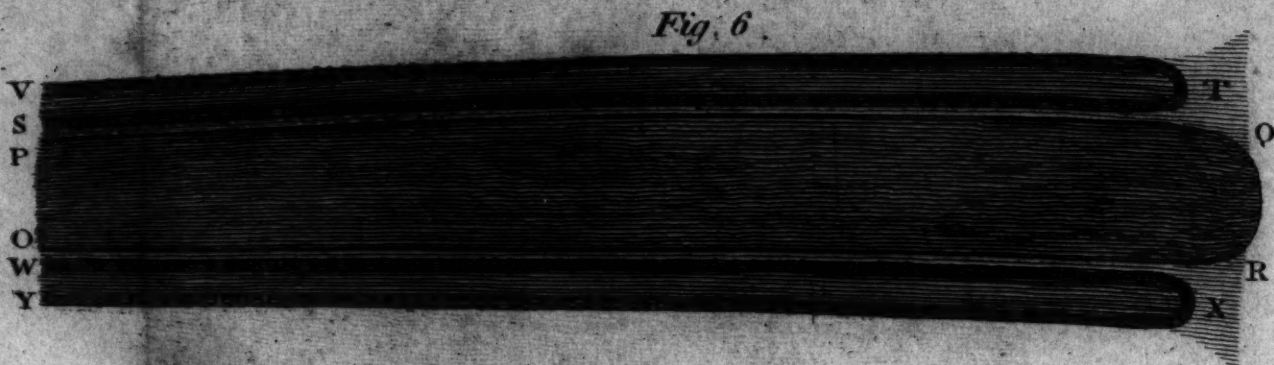
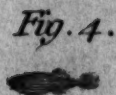
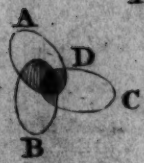
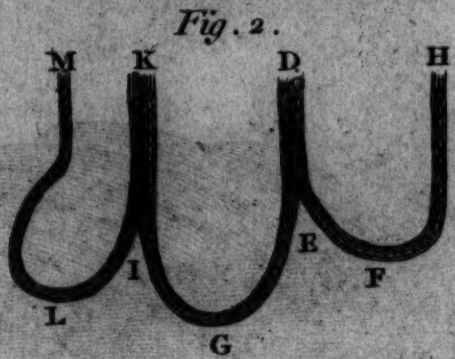


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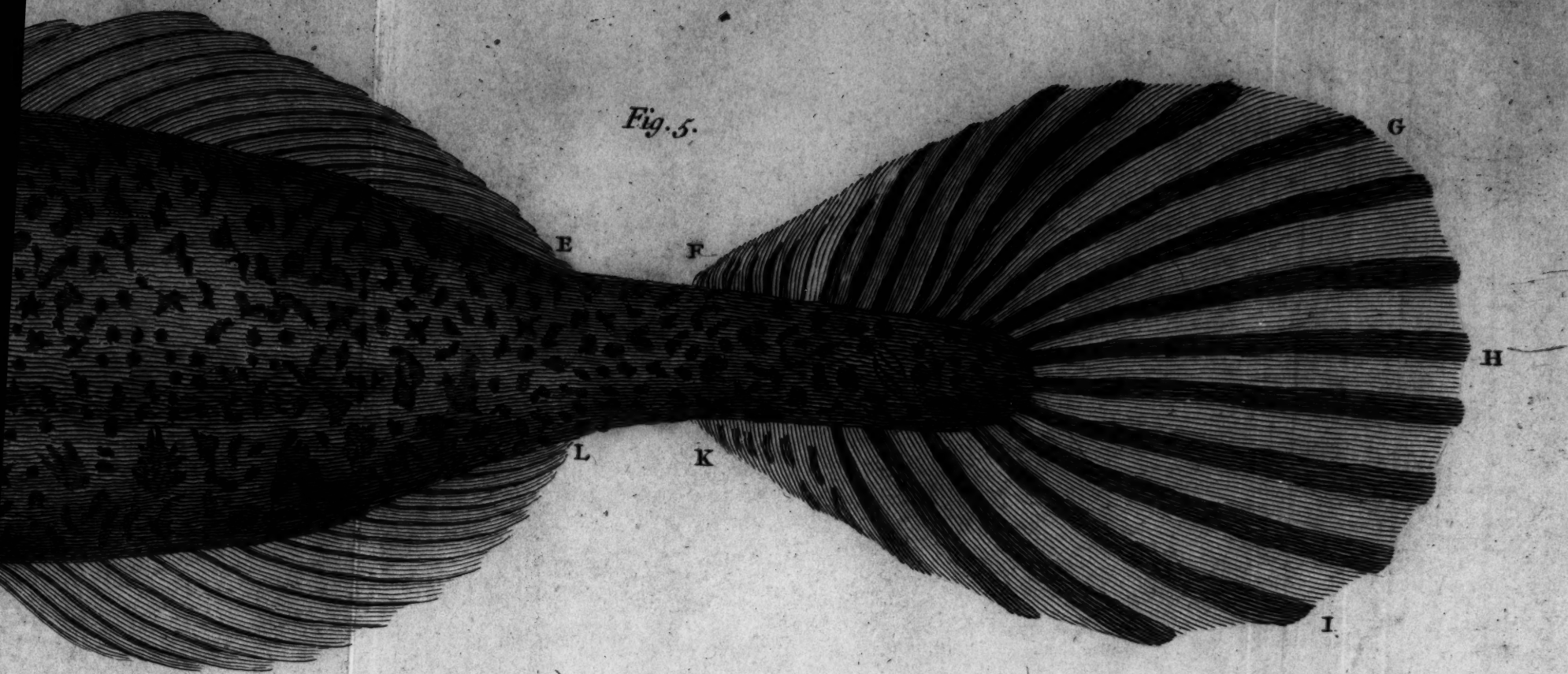
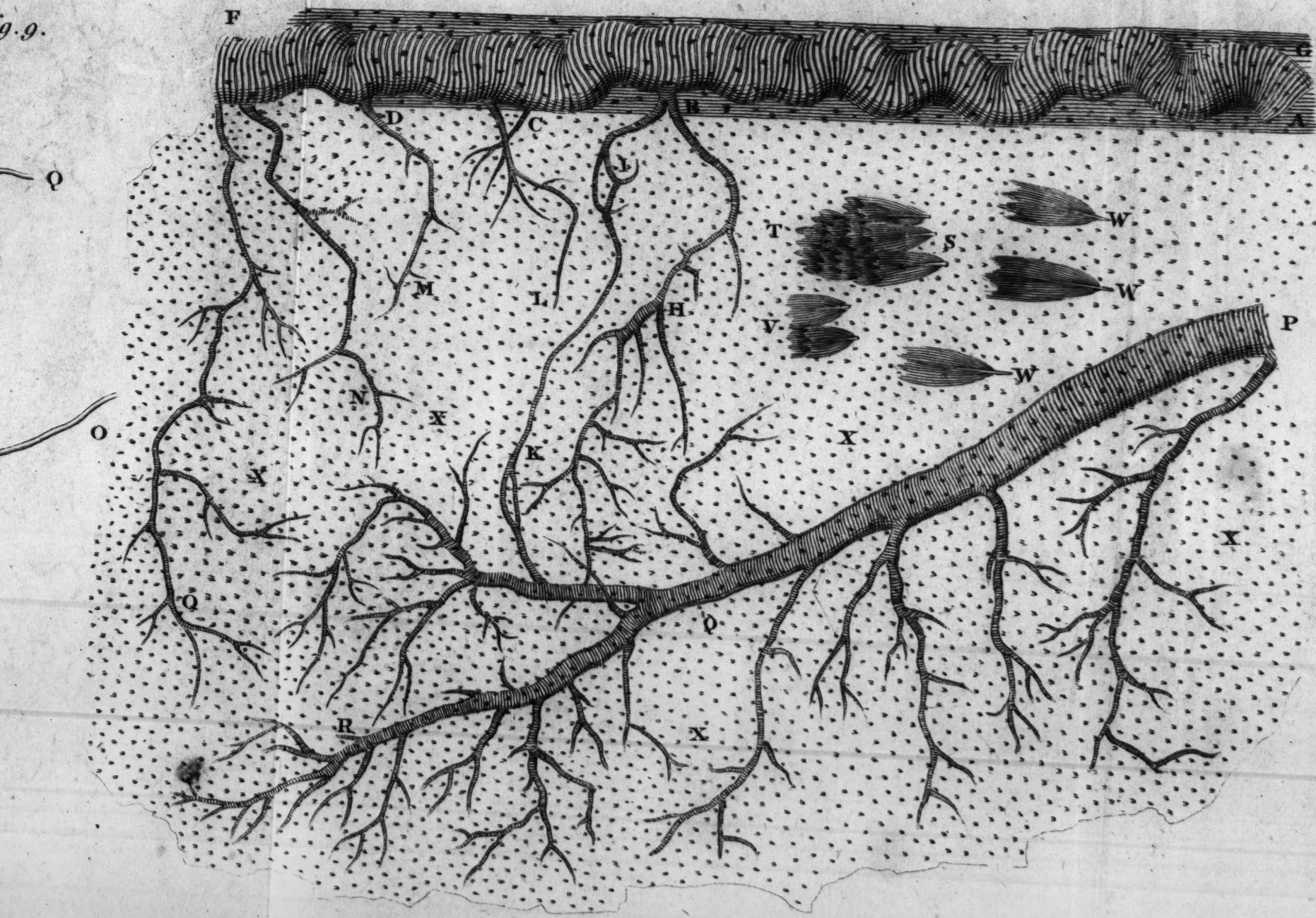


Fig. 11.



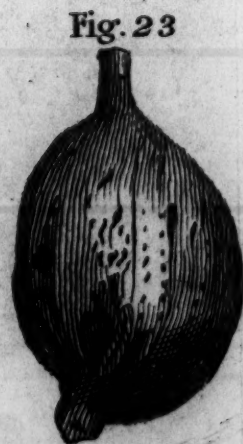
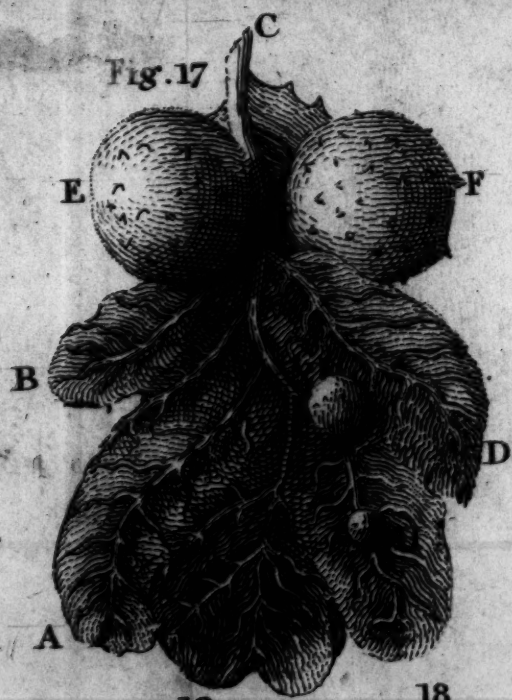
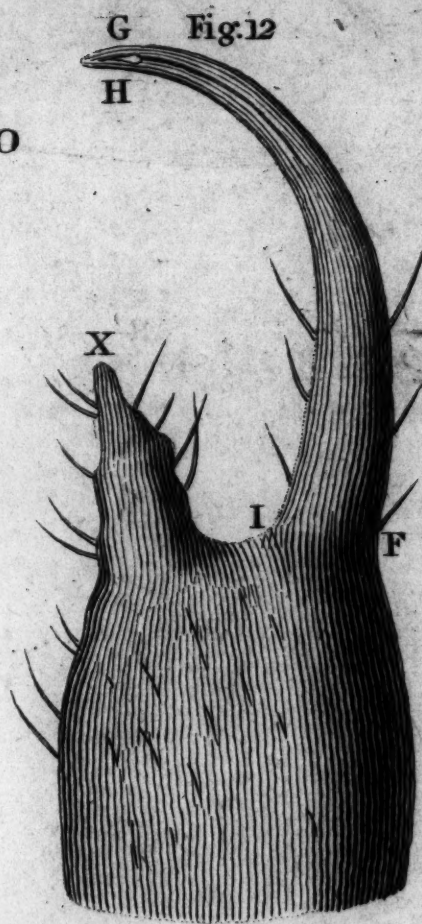
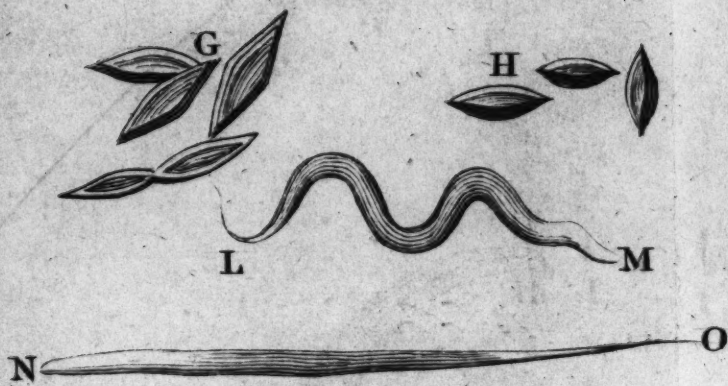
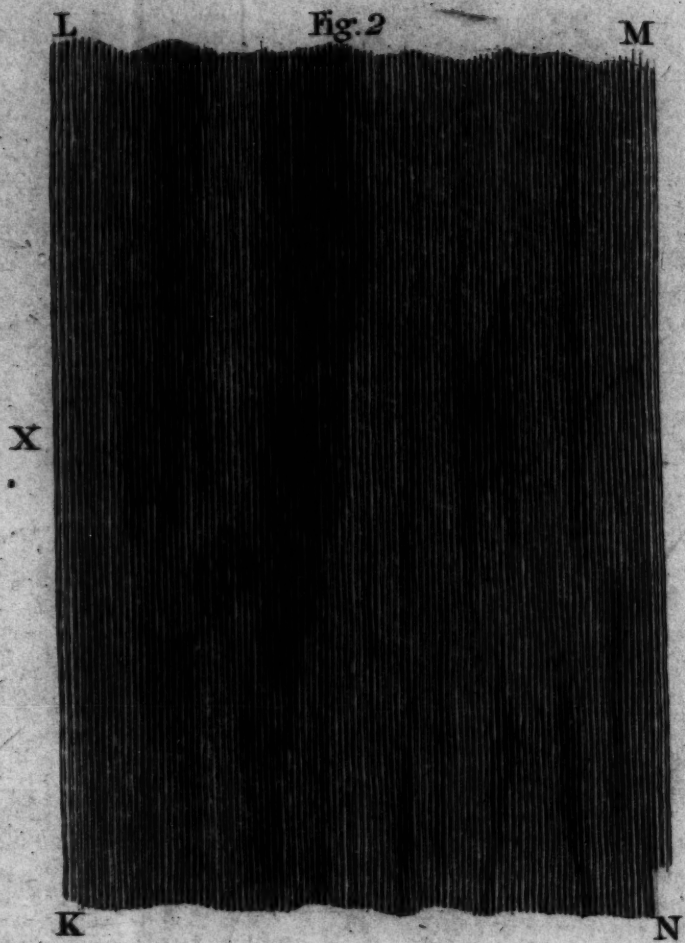
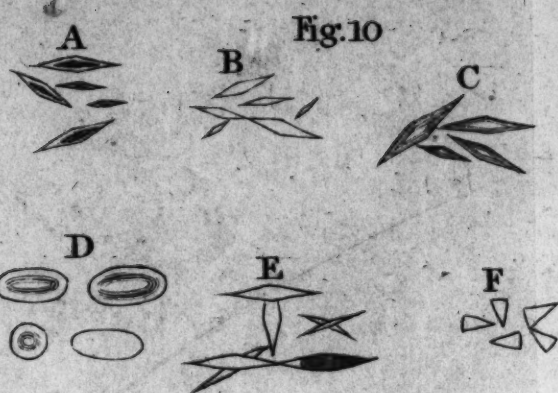
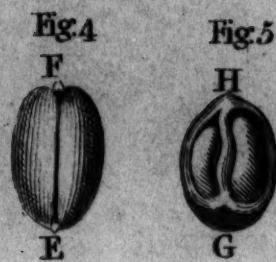
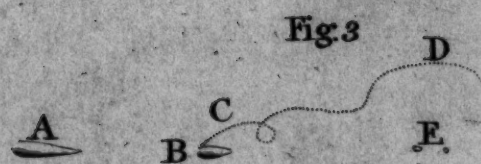


Plate V

Fig.6



Fig.7



Fig.9

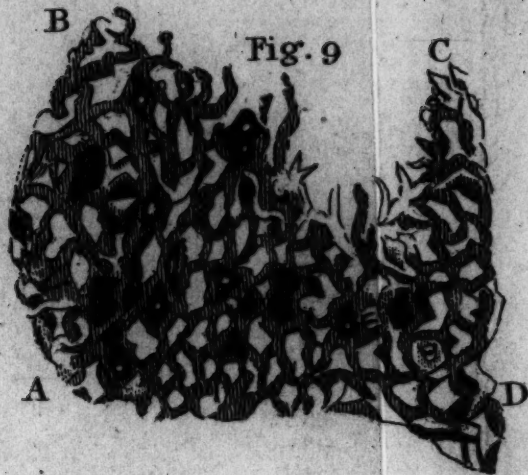


Fig.8



Fig.15

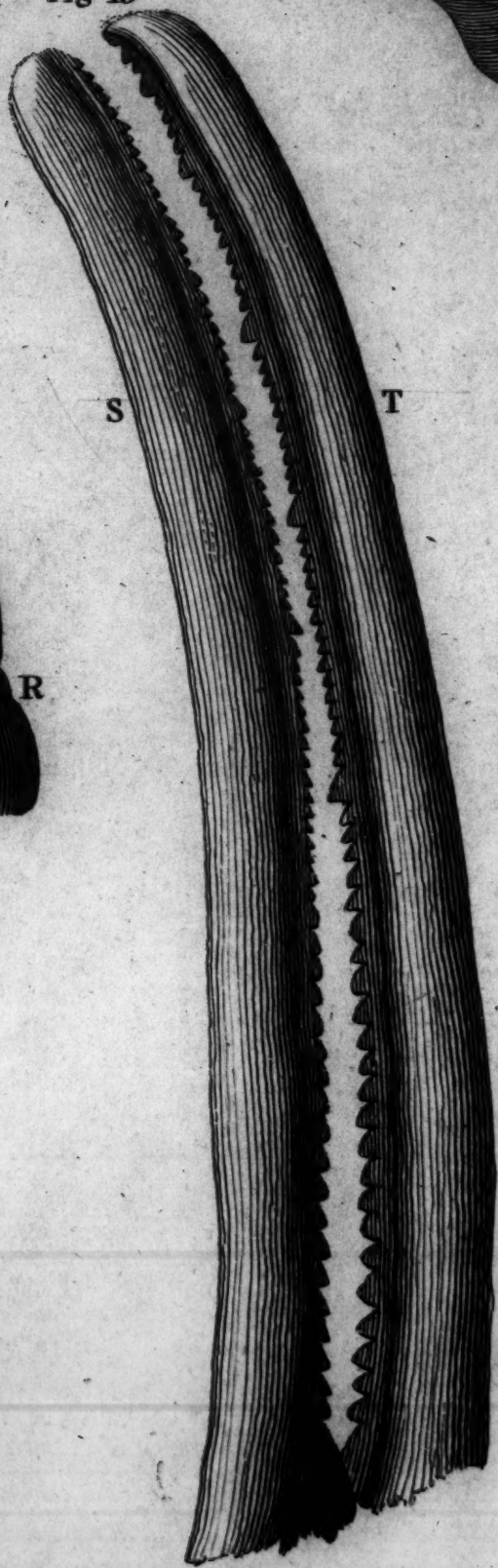


Fig.14



Fig.13

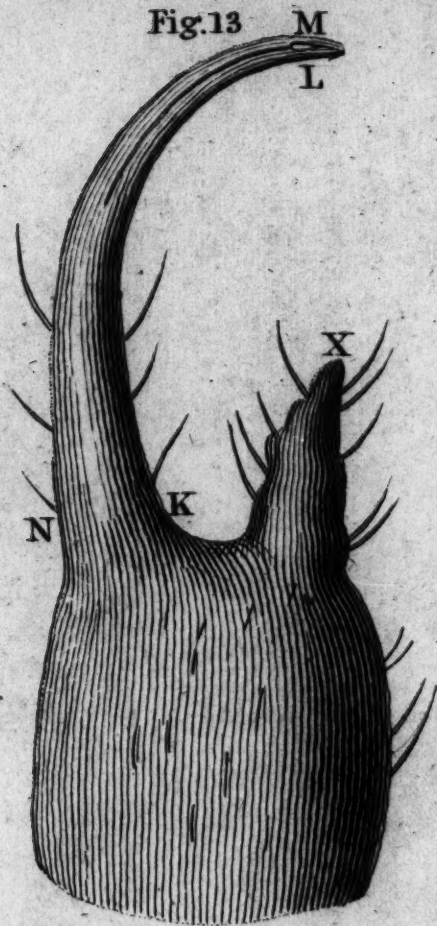


Fig.25



Fig.27



Fig.26



Fig.16



Fig. 1.

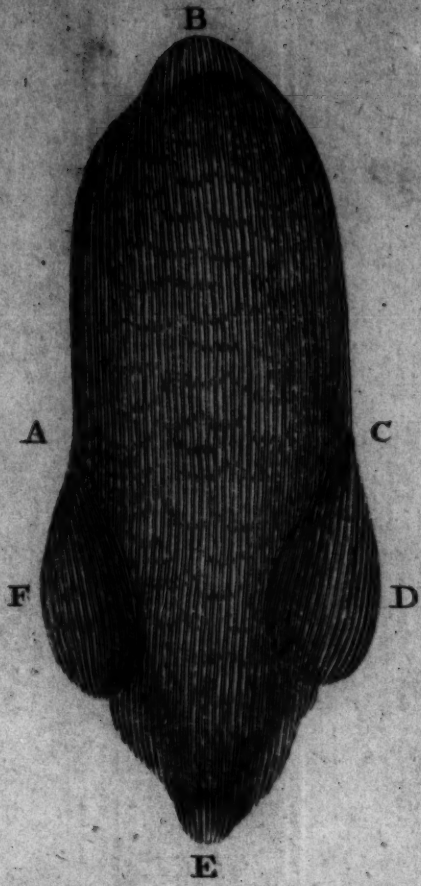


Fig. 2.

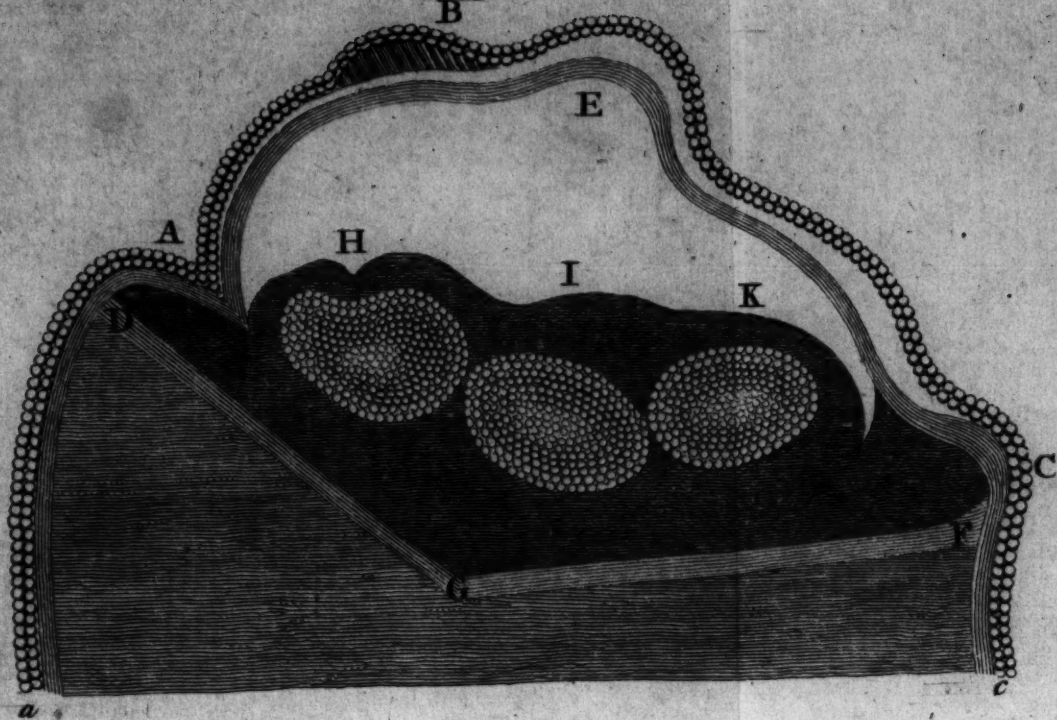


Fig. 3.



Fig. 8.

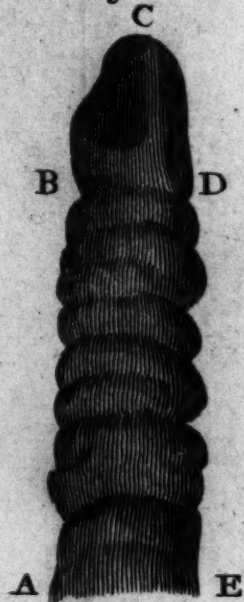


Fig. 10.

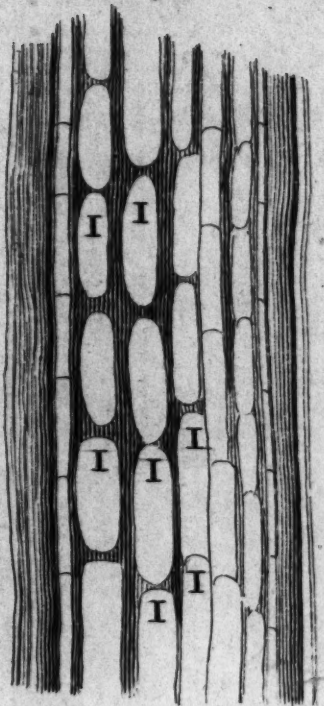


Fig. 11.

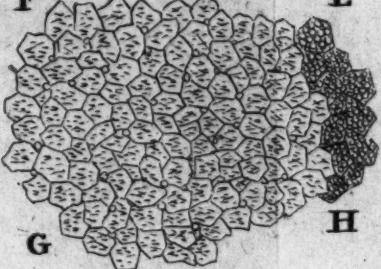


Fig. 13.



Fig. 12.

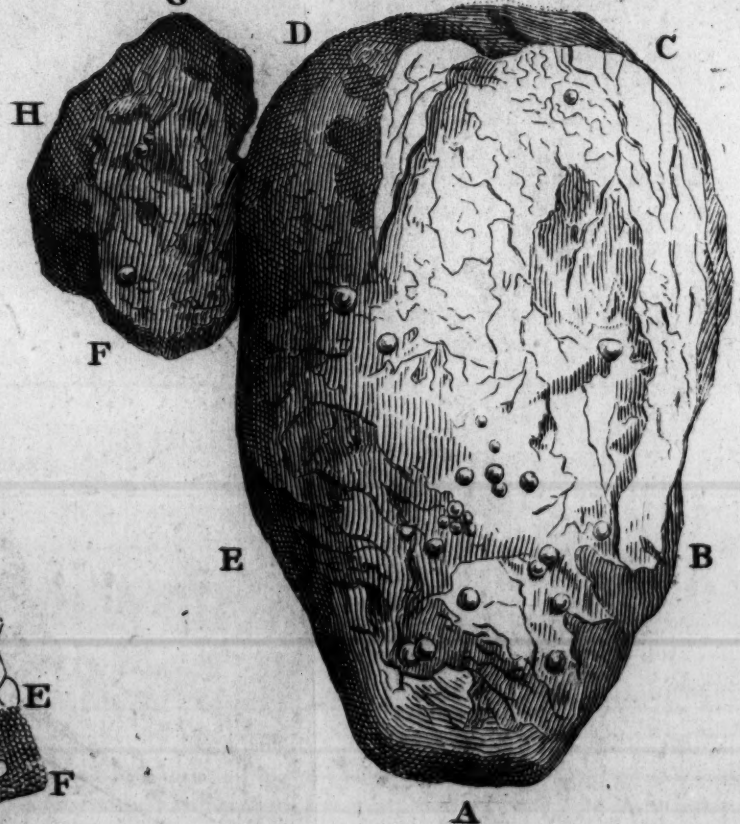


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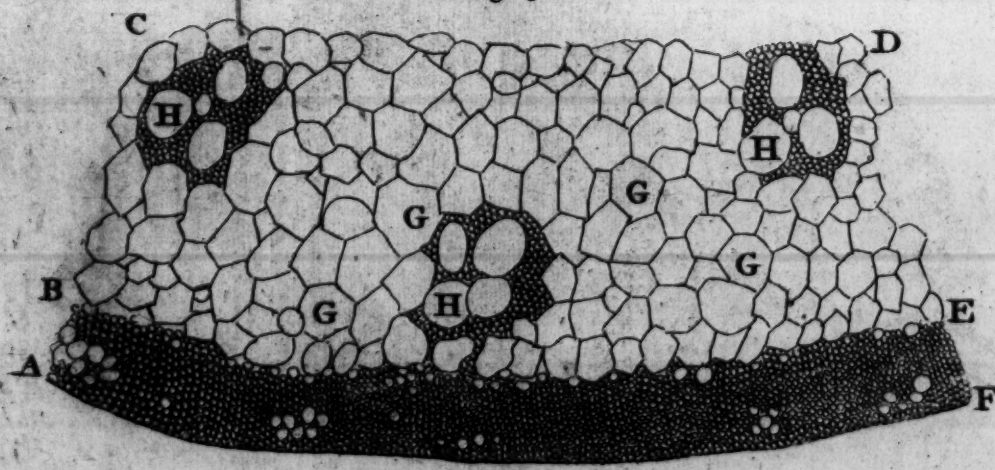


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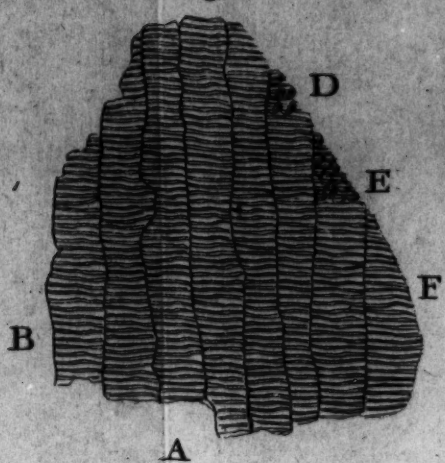


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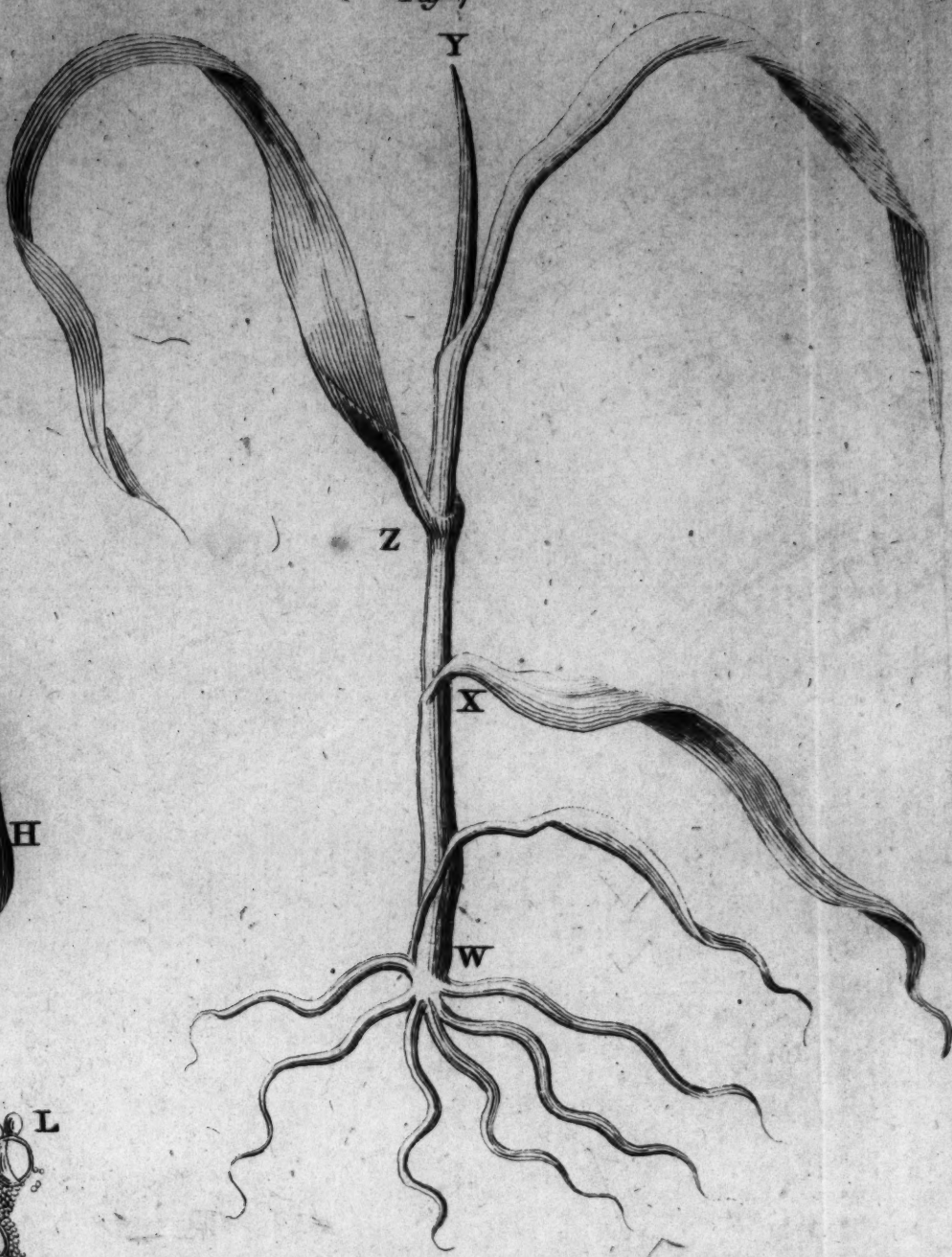


Fig. 5.



Fig. 6.

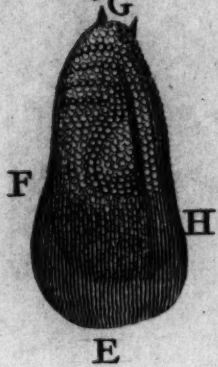


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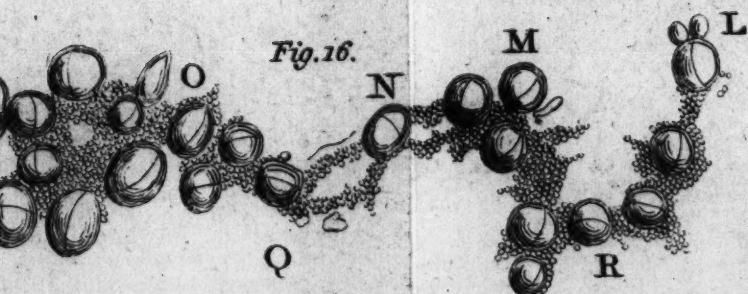


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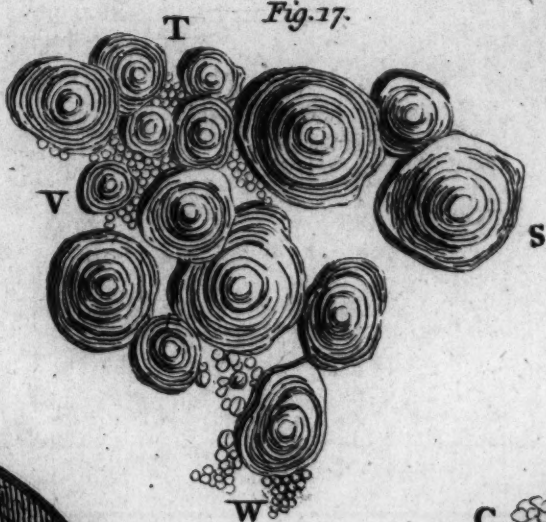


Fig. 14.



Fig. 15.

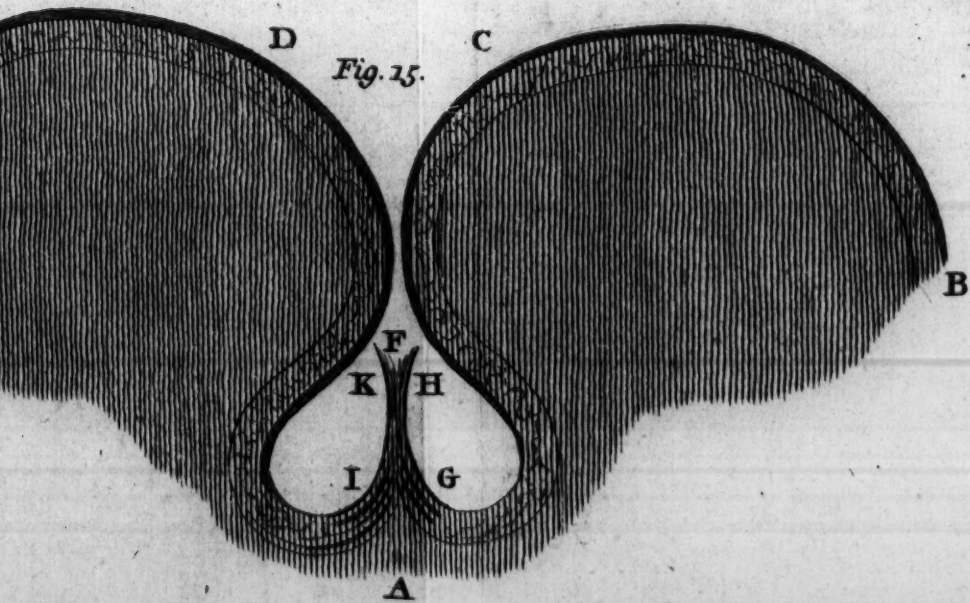


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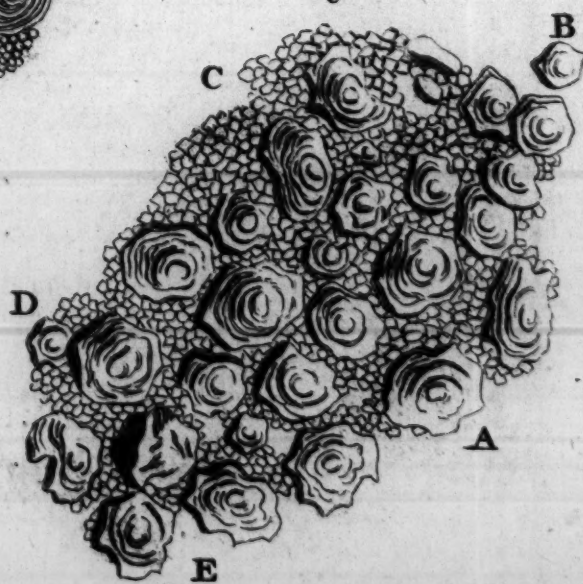


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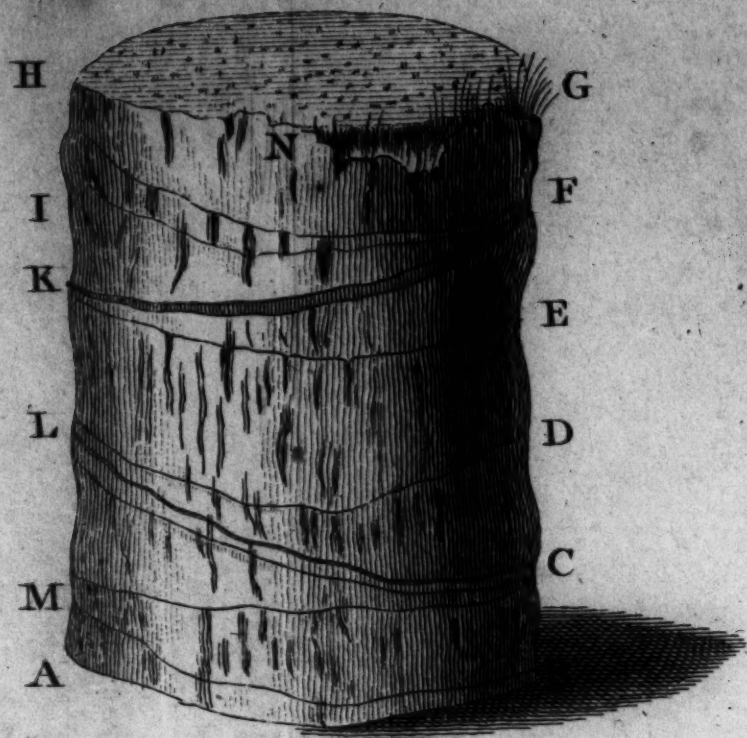


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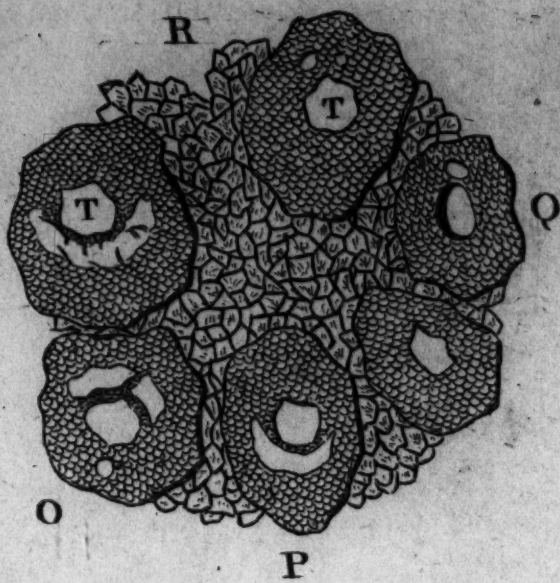


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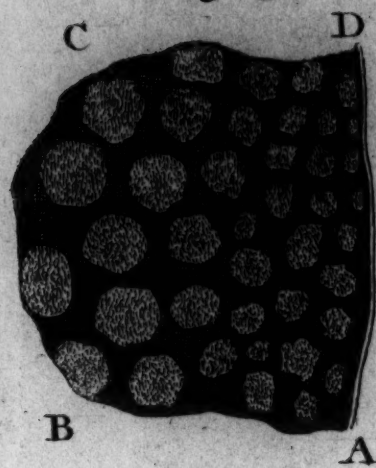


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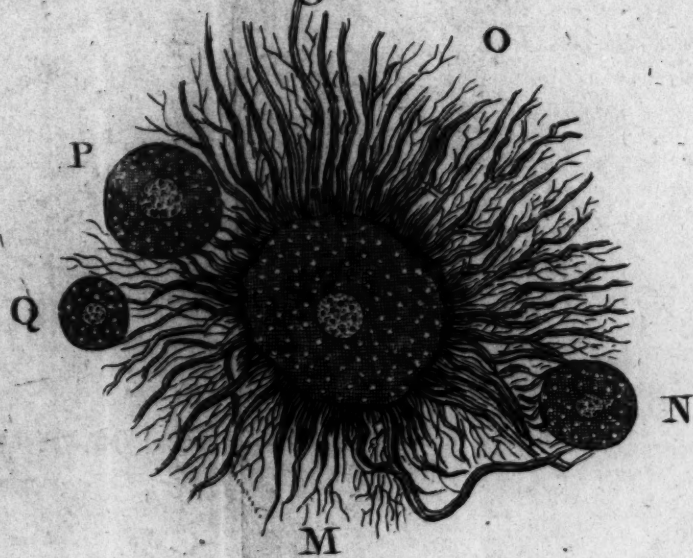


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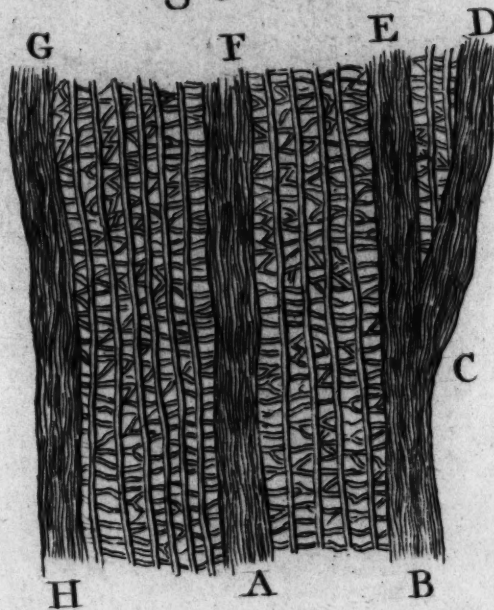


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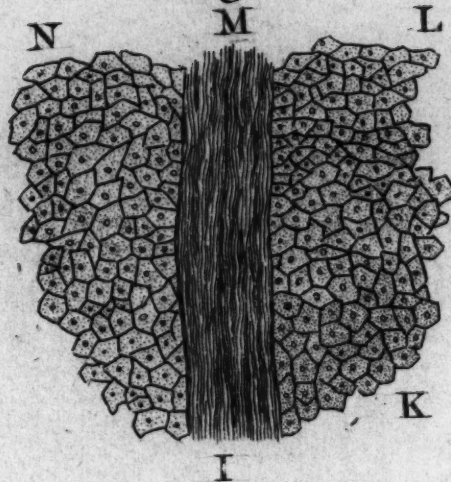


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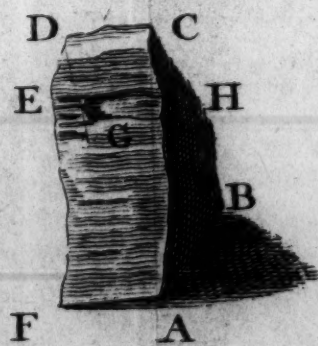


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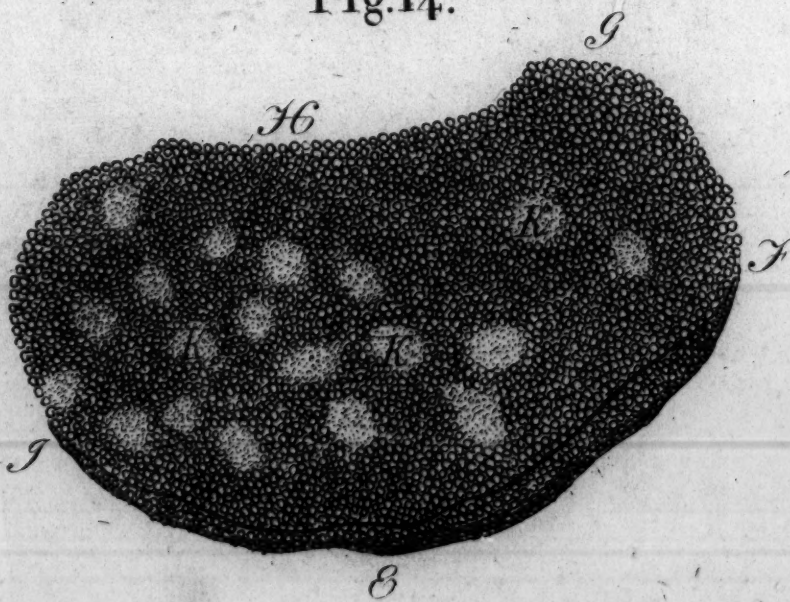


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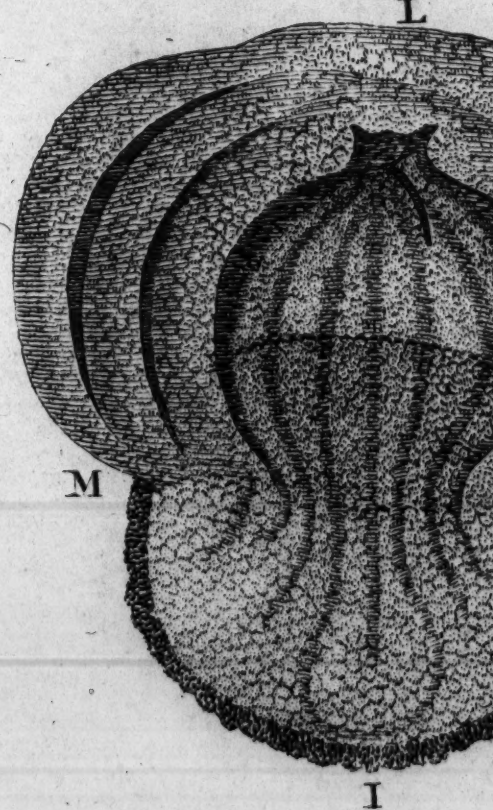


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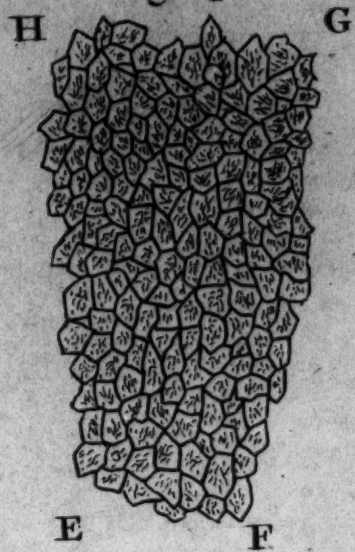


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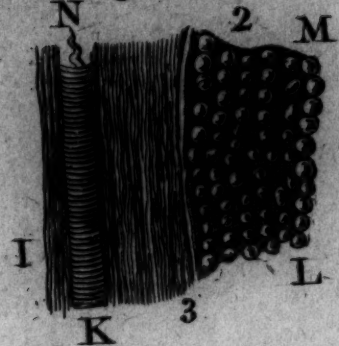


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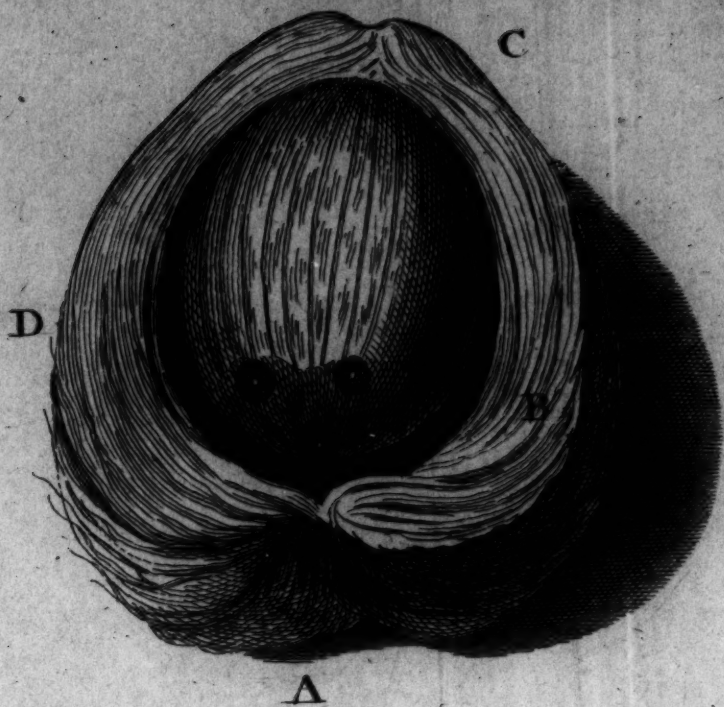


Fig. II.

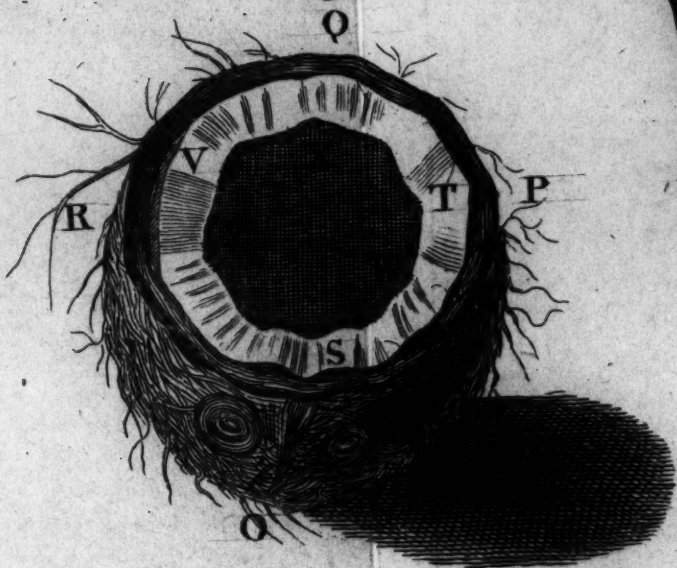


Fig. 6.



Fig. 12.

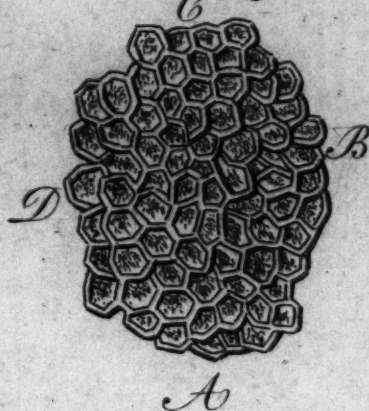


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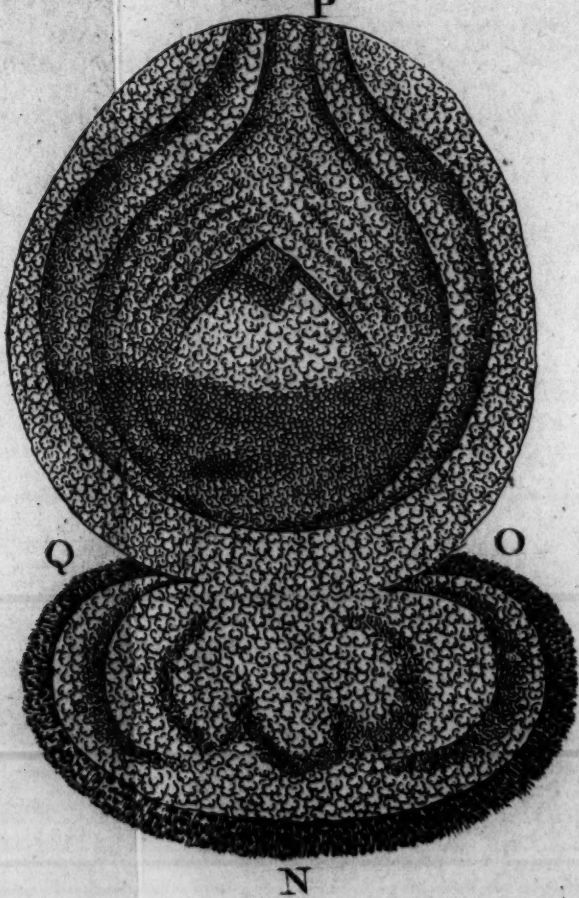
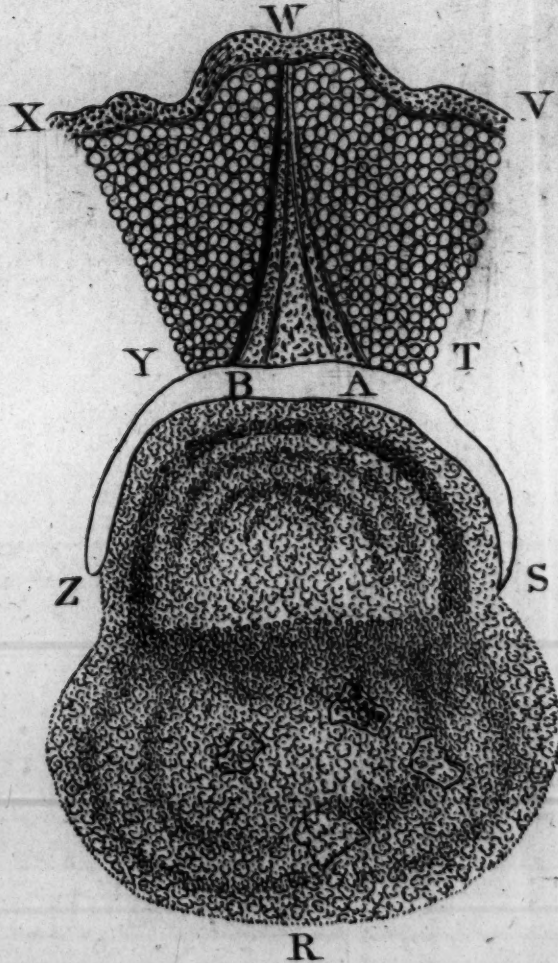


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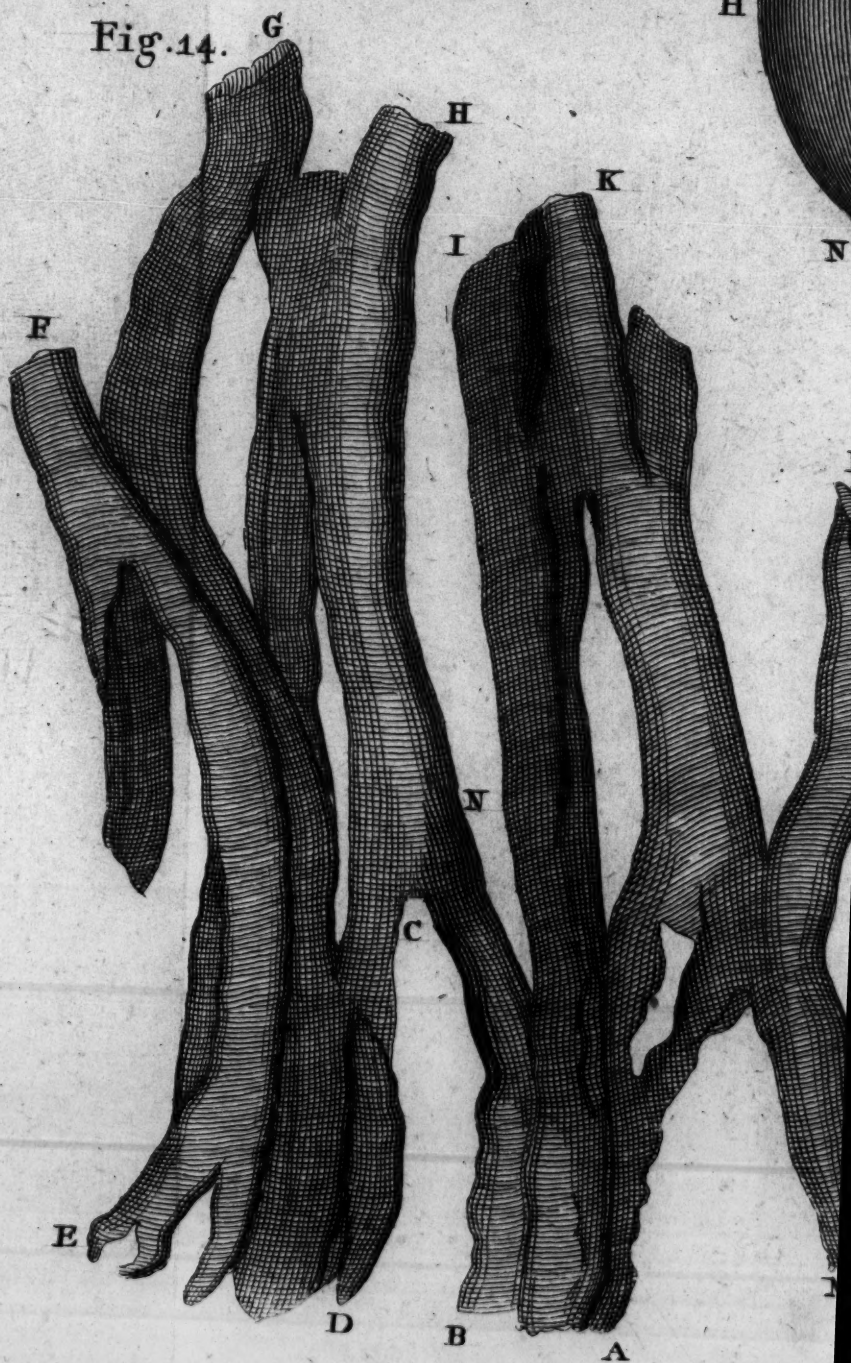
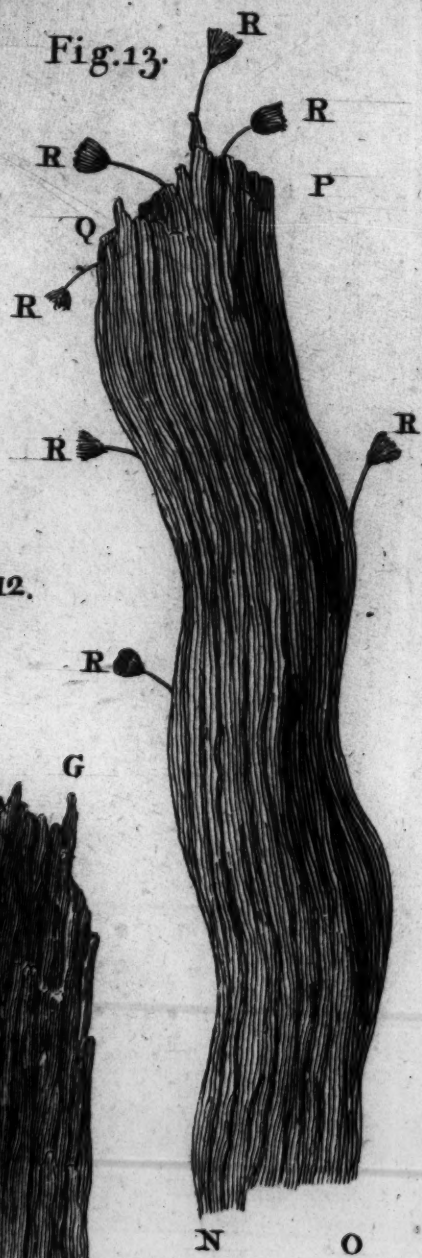
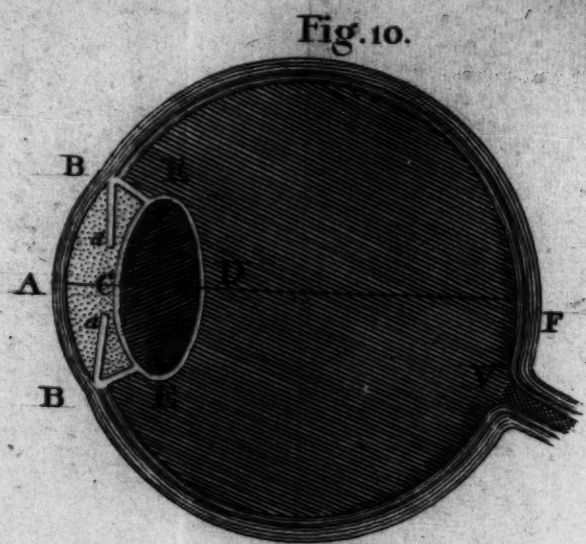
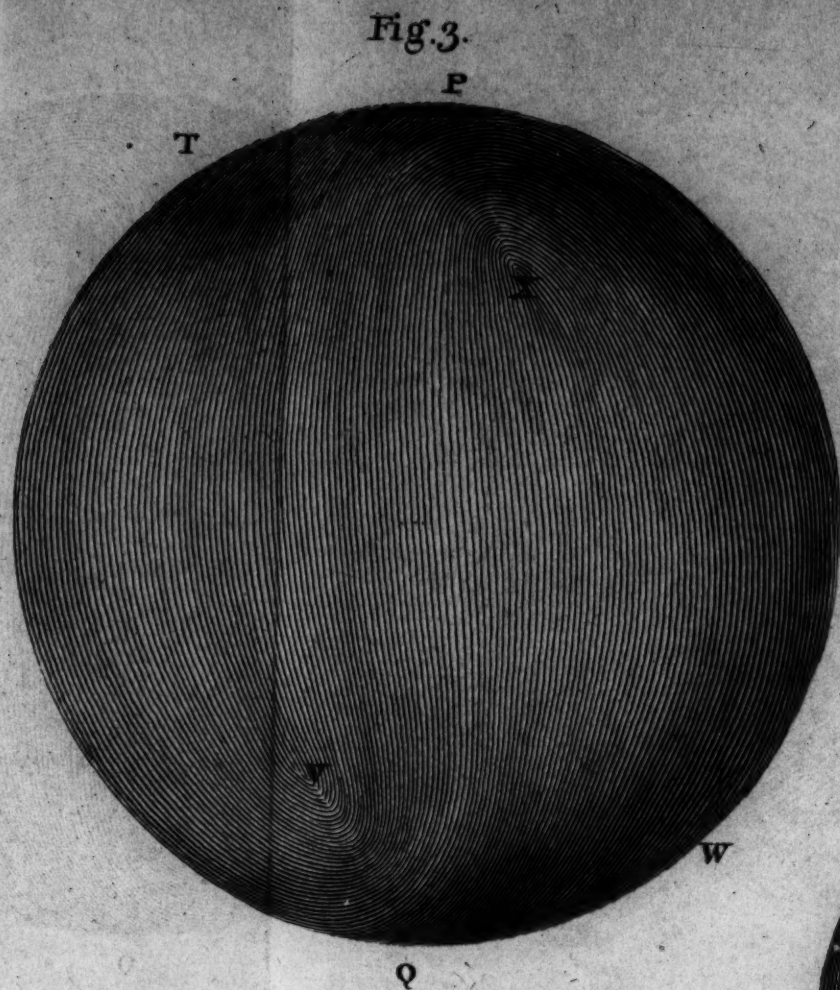
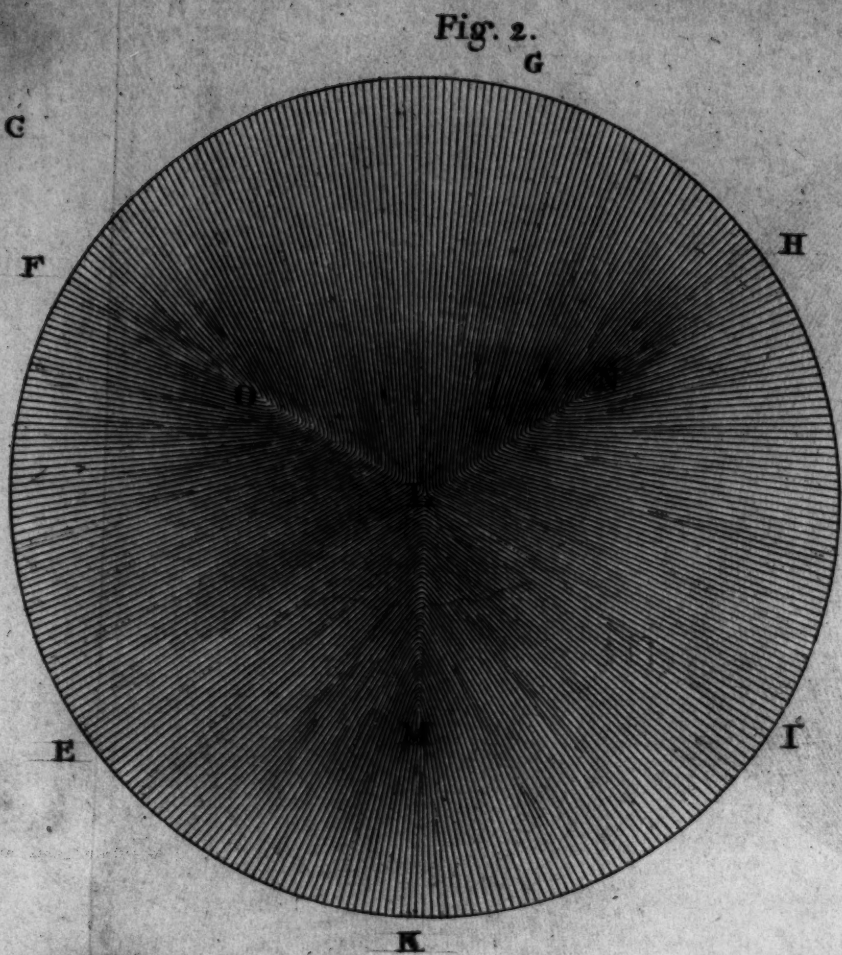


Fig. 12.



Fig. 4.

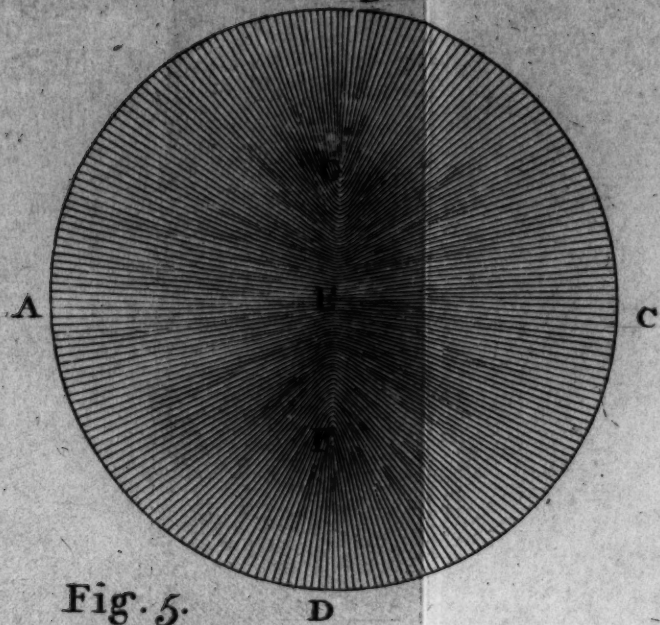


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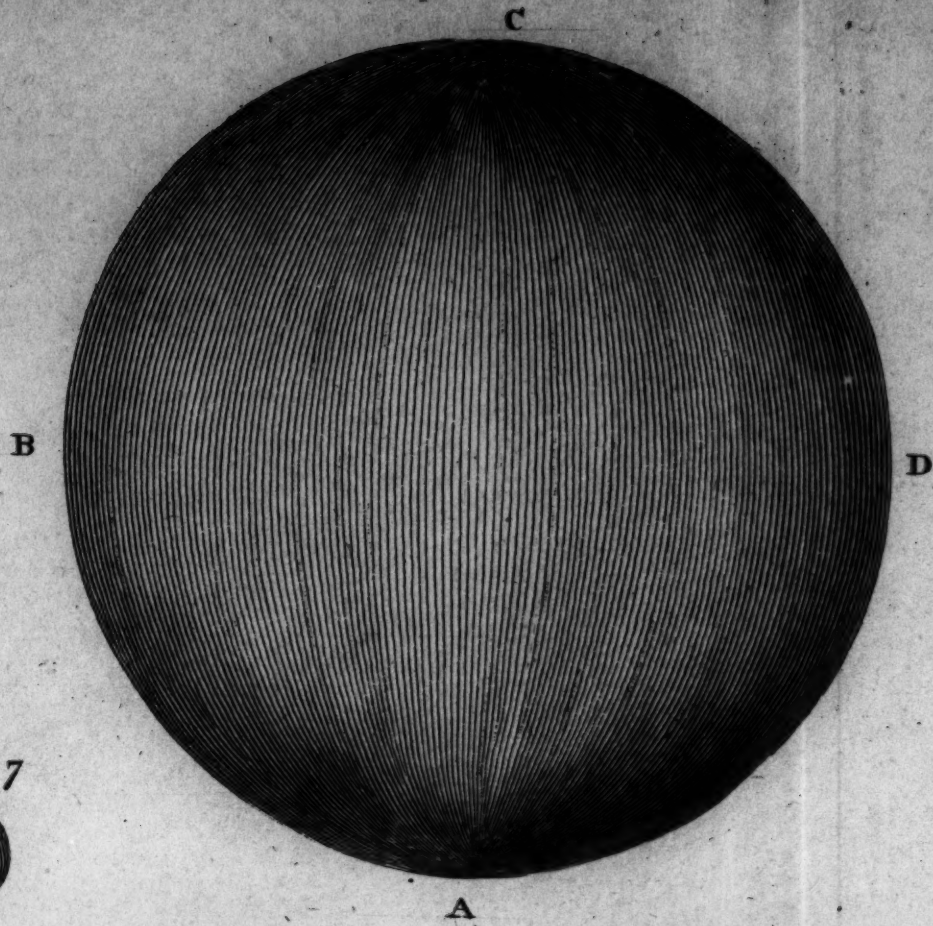


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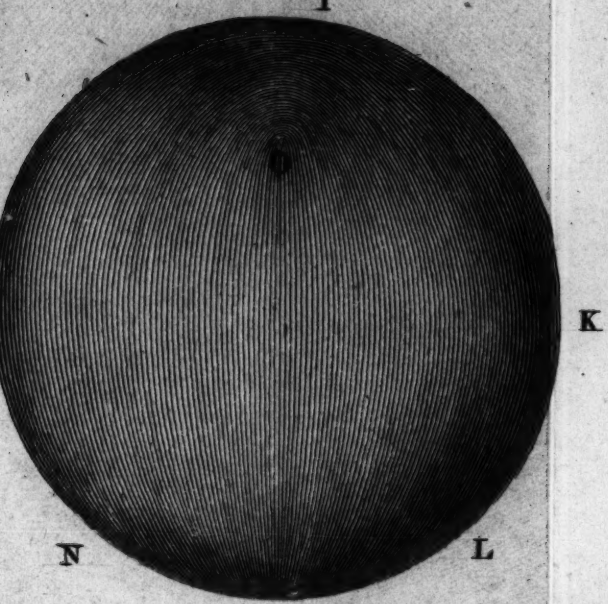


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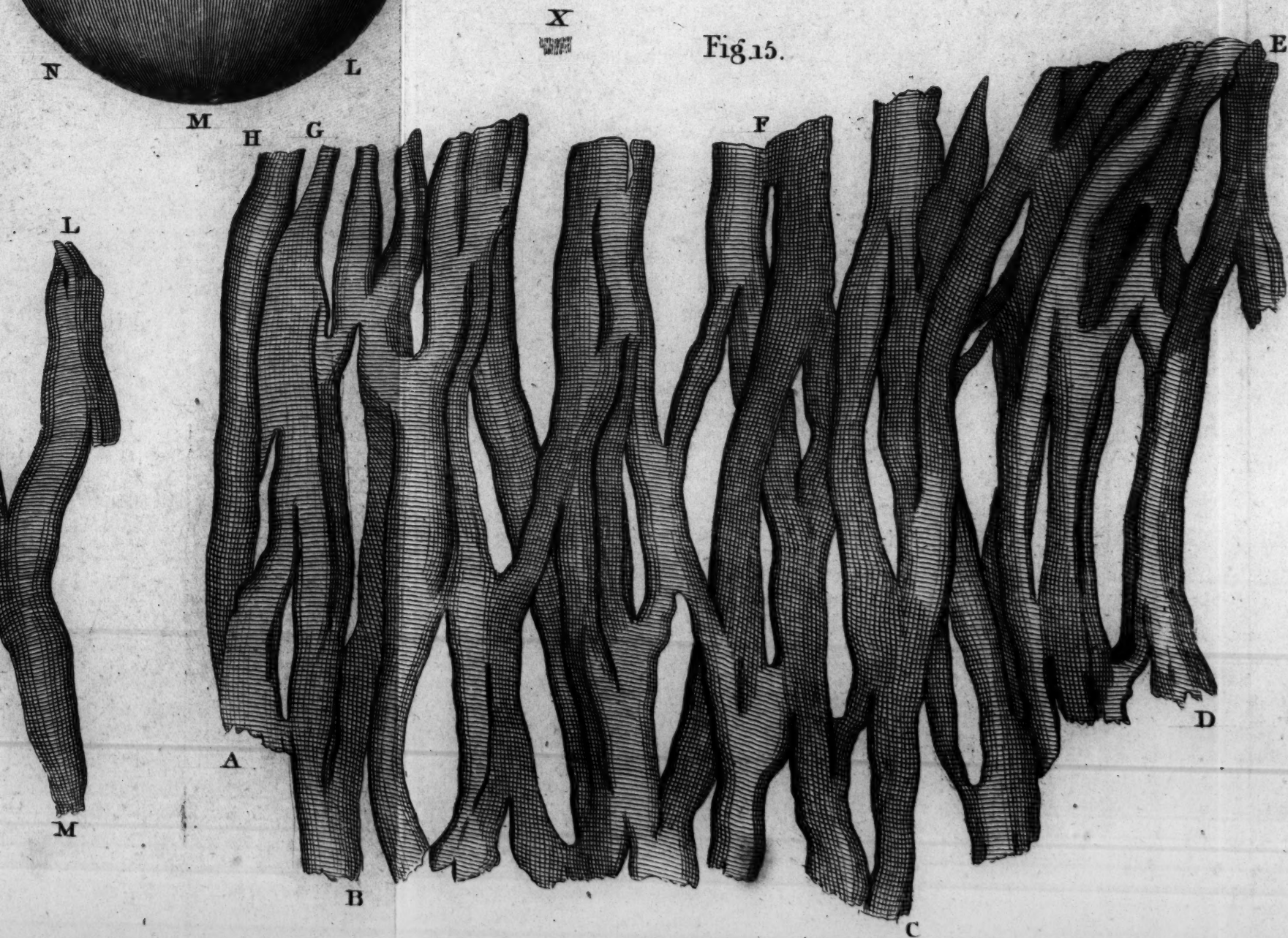
Fig. 8.



Fig. 9.



Fig. 15.



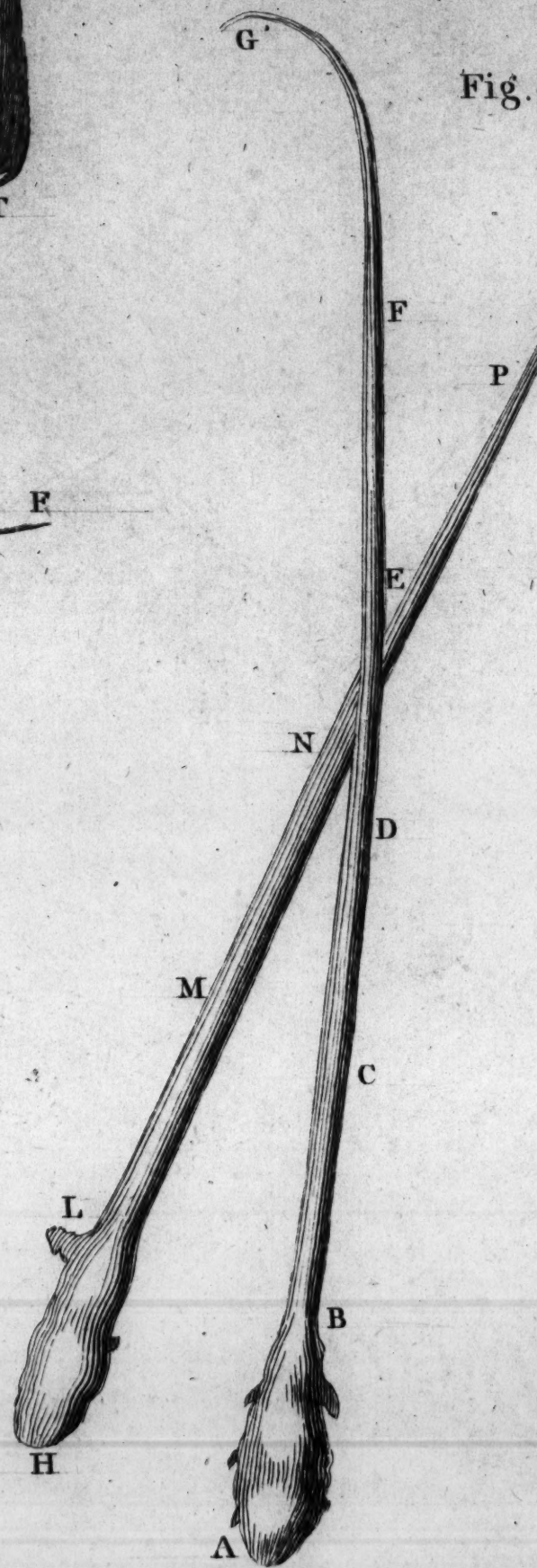
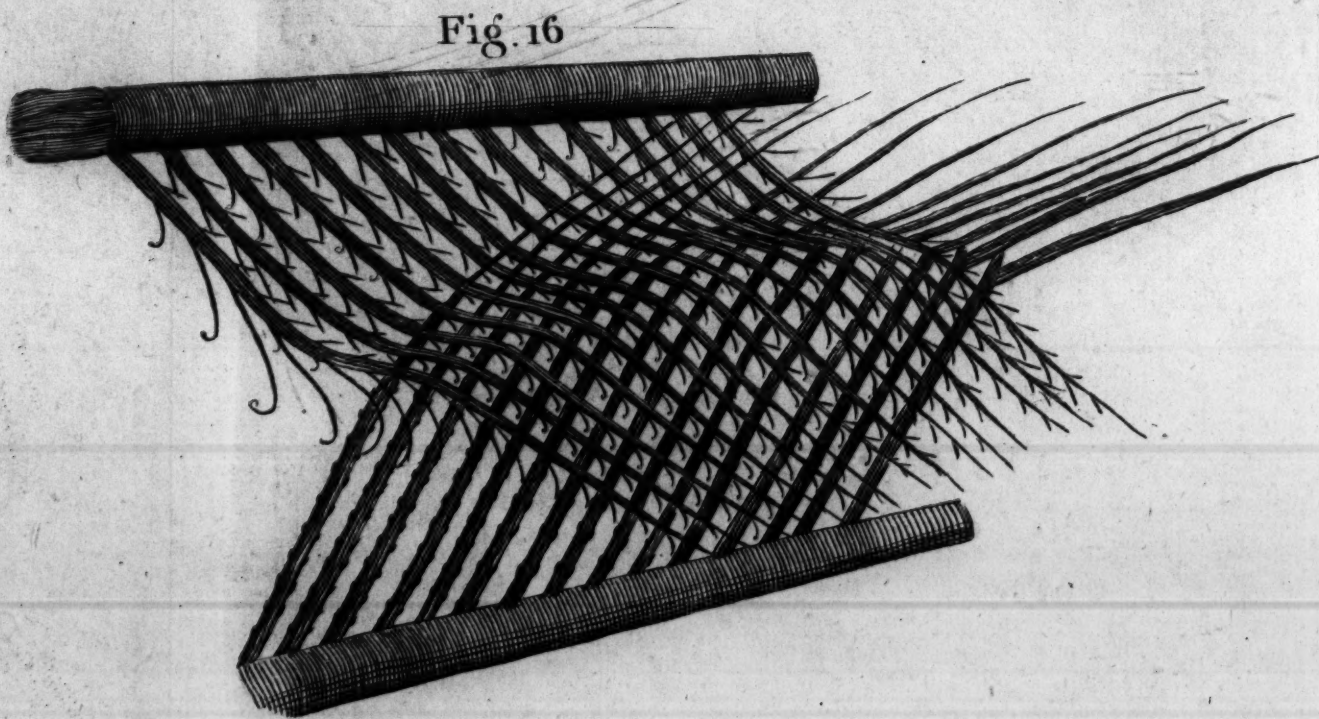
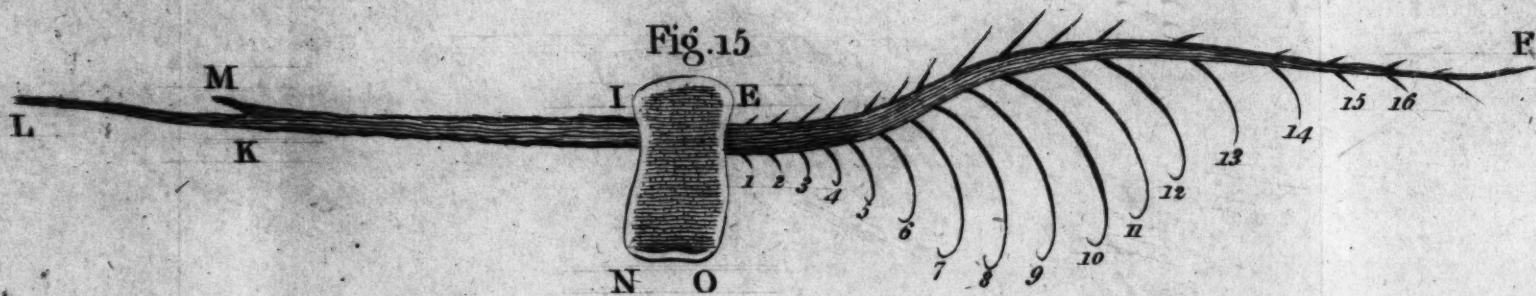
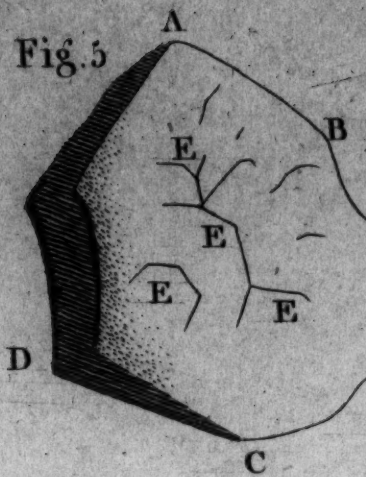


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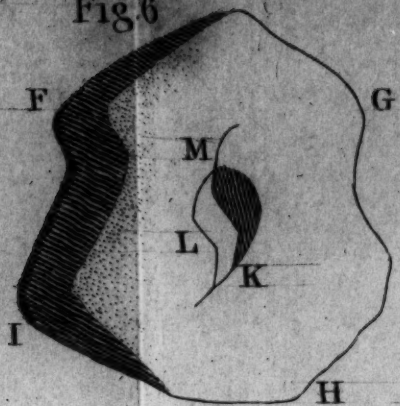


Fig. 7

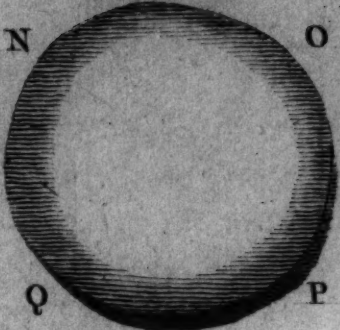


Fig. 8

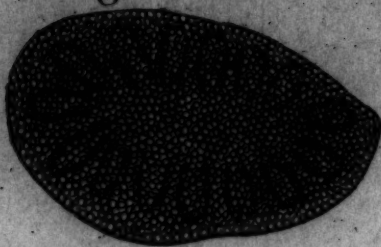


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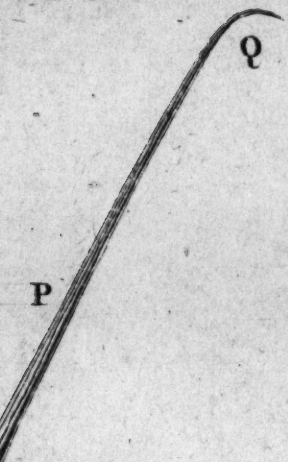


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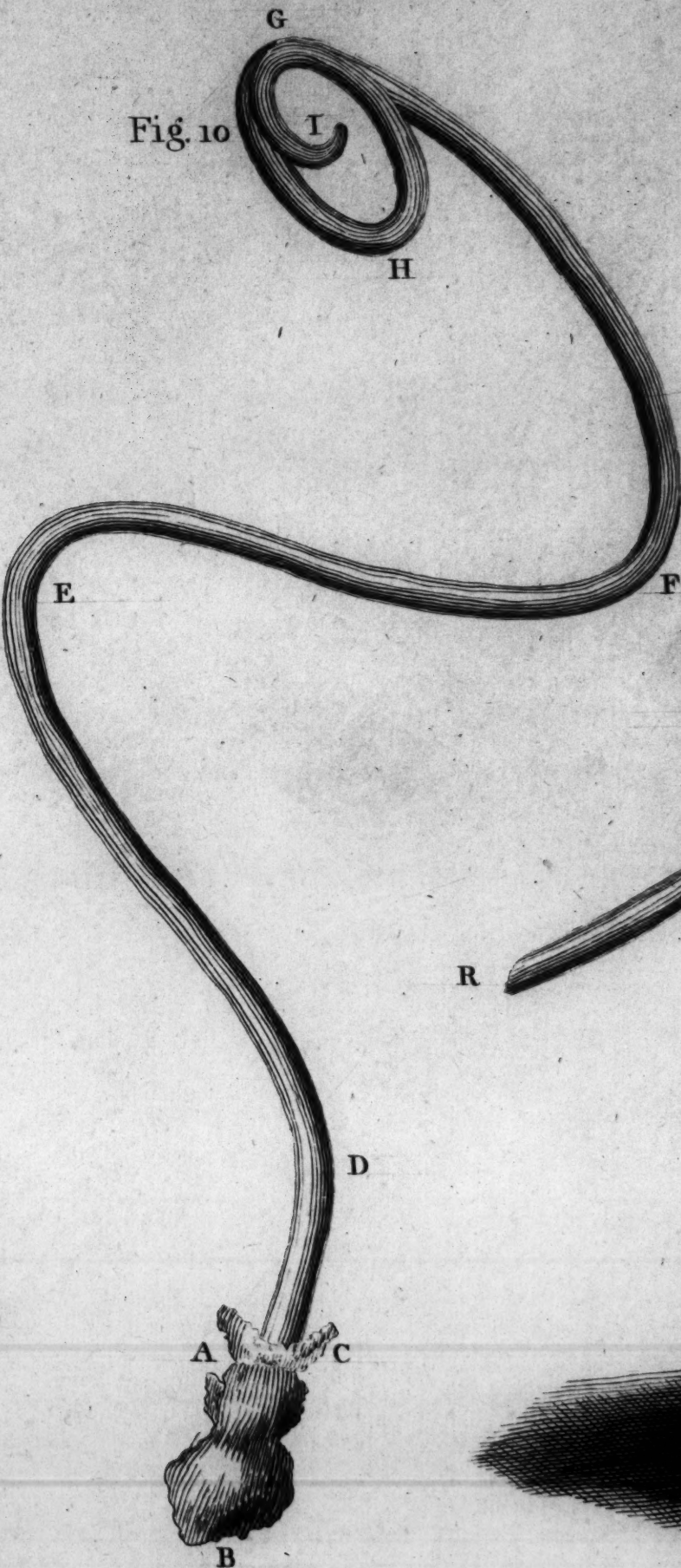


Fig. 14



Fig. 11



Fig. 13

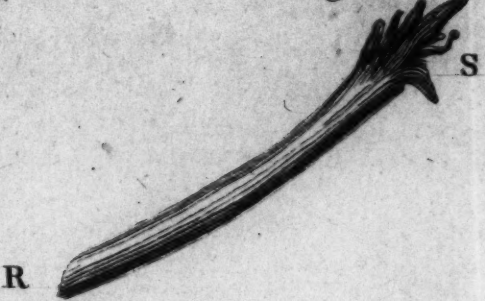
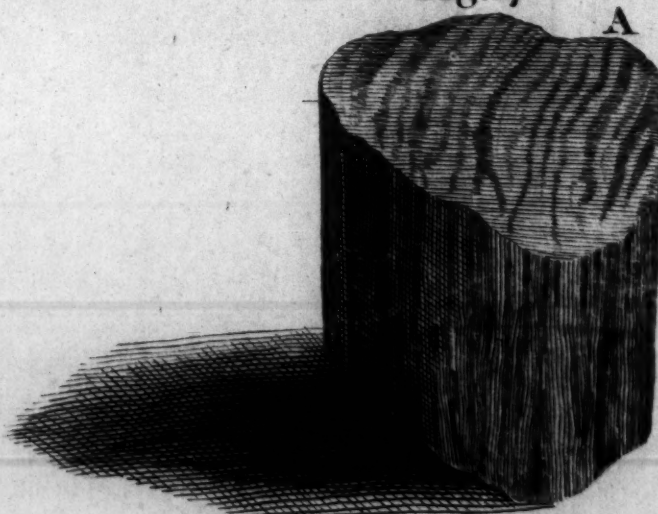


Fig. 12



Fig. 17



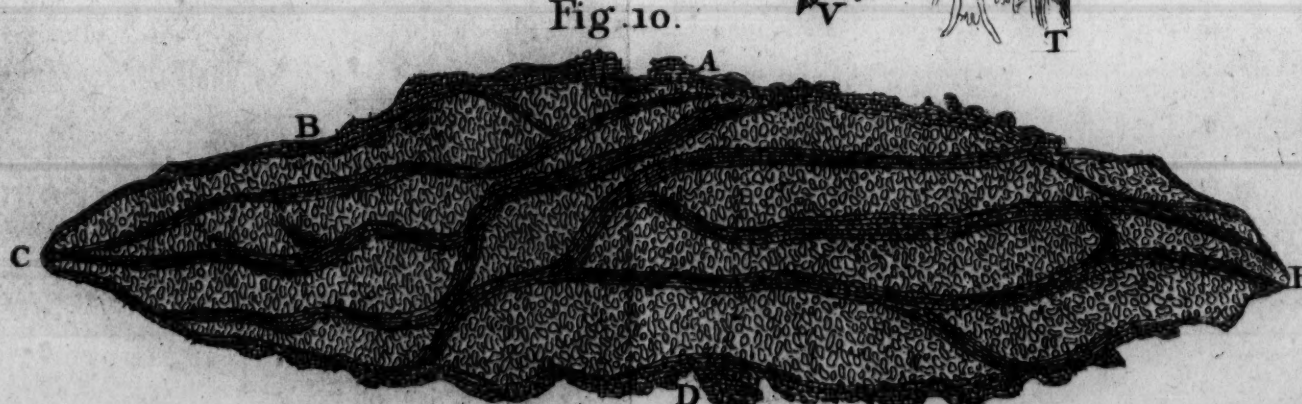
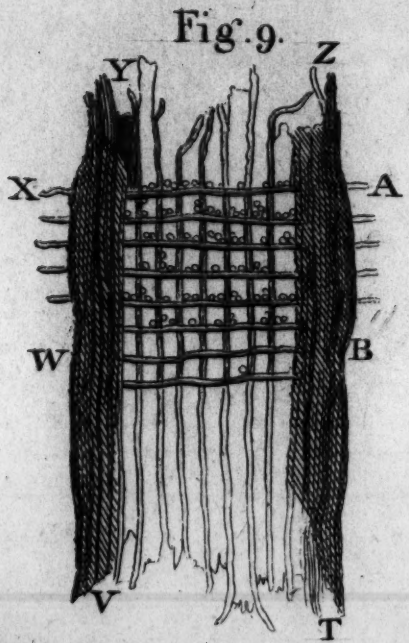
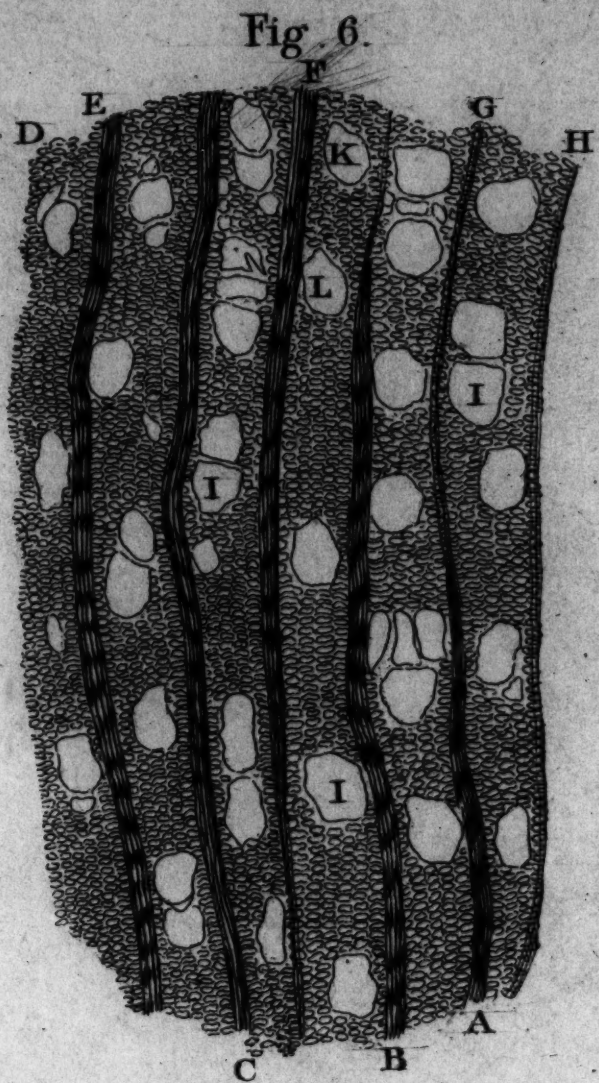
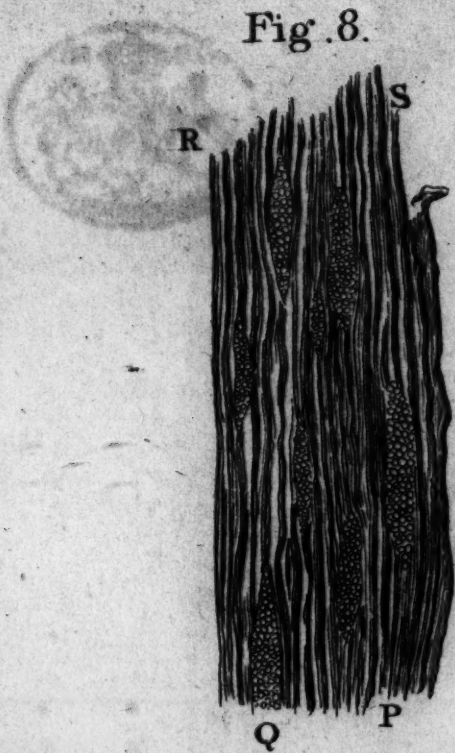
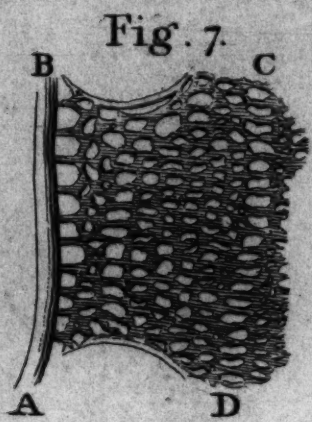
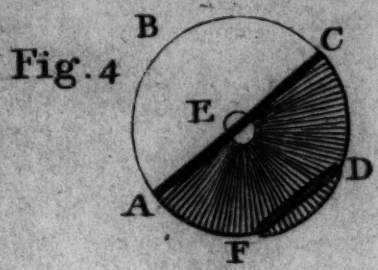
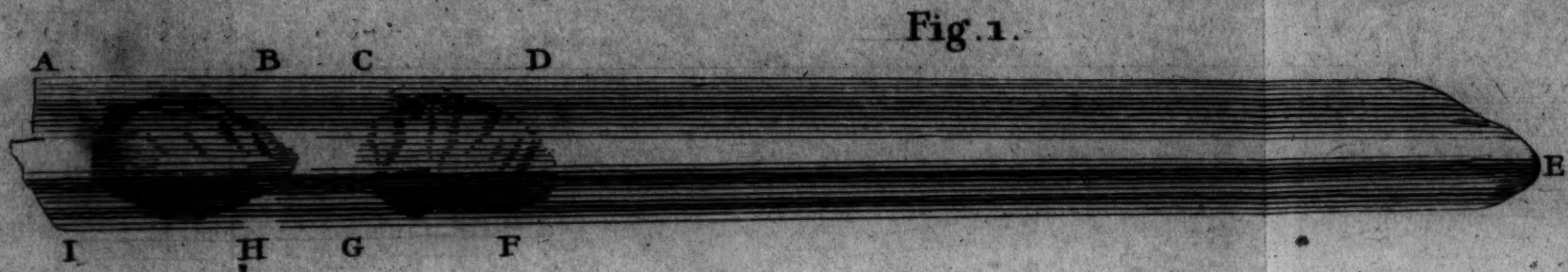


Fig. 2.



Fig. 13.



Fig. 14.



Fig. 15.



Fig. 16.



Fig. 17.



Fig. 22.



Fig. 18.



Fig. 20.

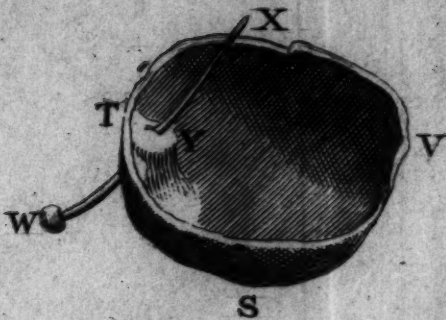


Fig. 5.

Fig. 21.



Fig. 25.

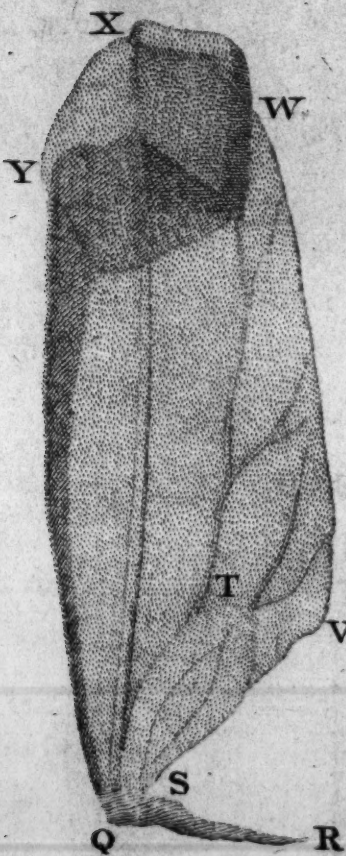


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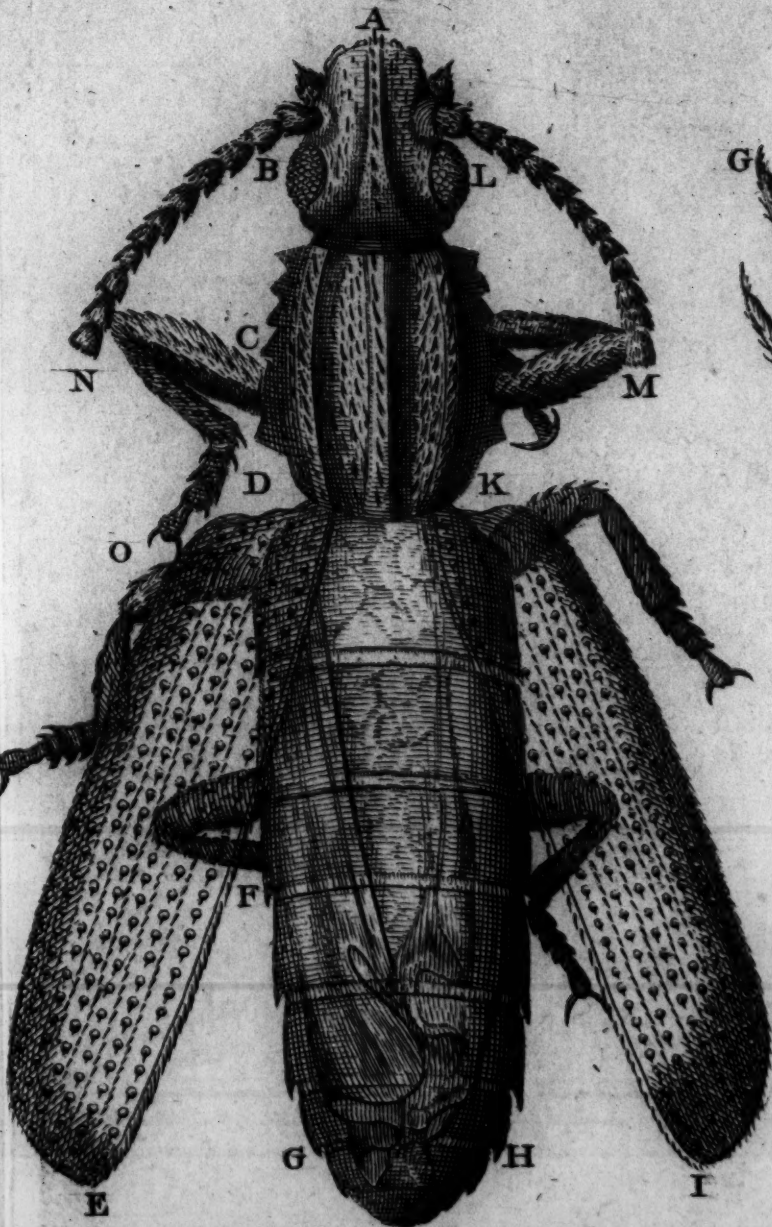


Fig. 23.

